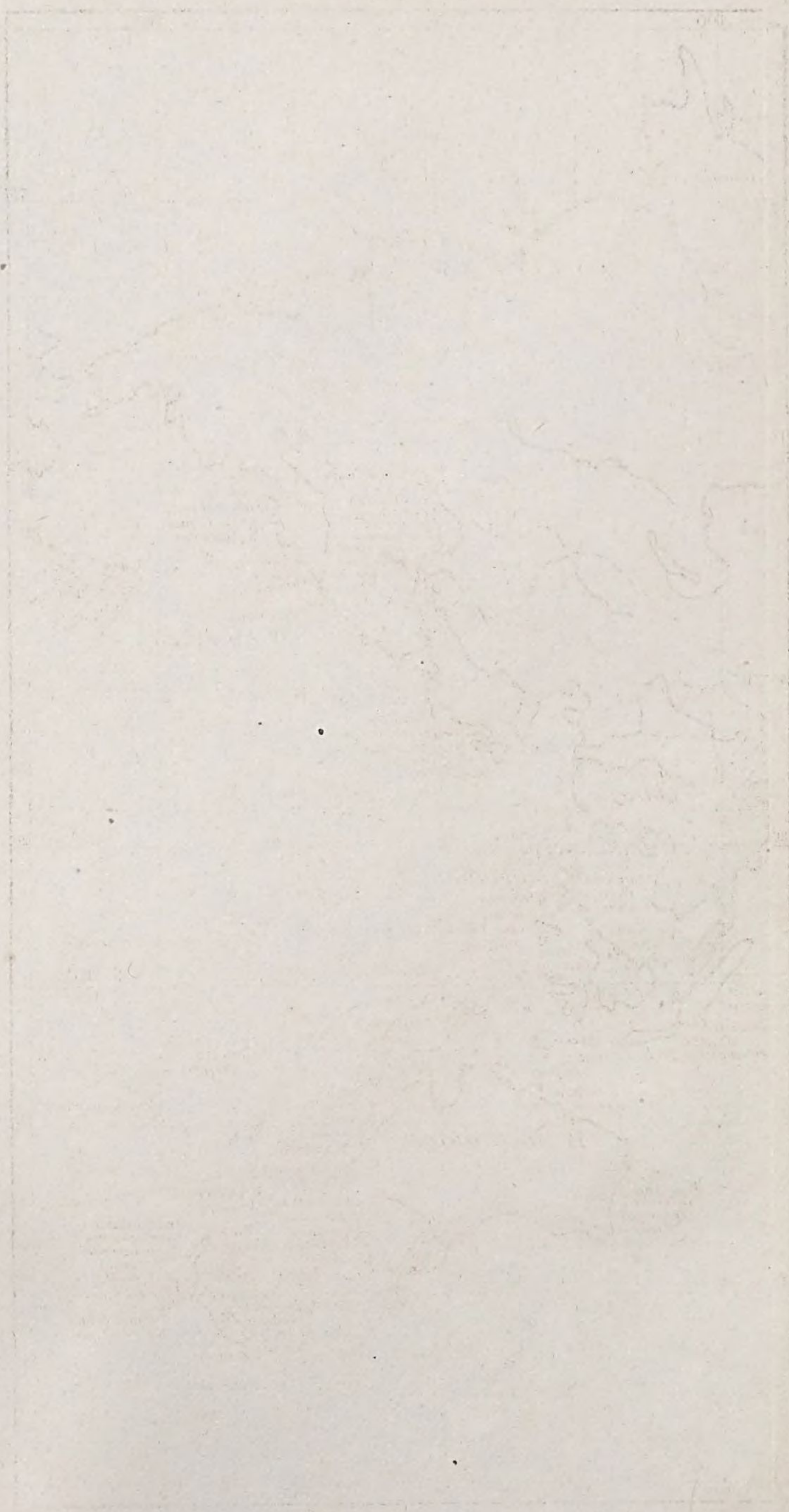
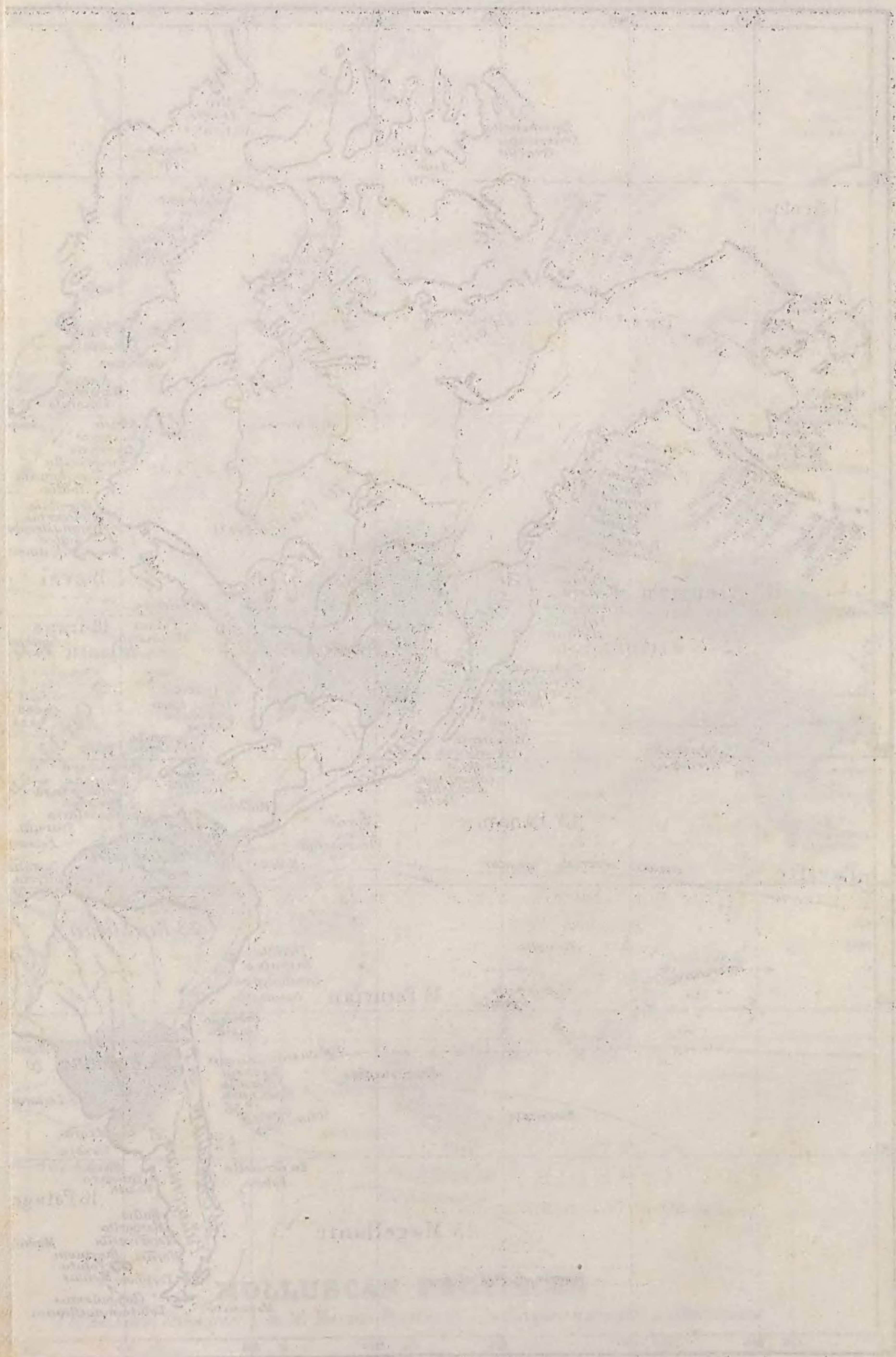


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STRUCTURAL
AND
SYSTEMATIC
CONCHOLOGY:

AN INTRODUCTION TO THE STUDY OF THE

MOLLUSCA.

VOL. I.

BY GEORGE W. TRYON, JR.

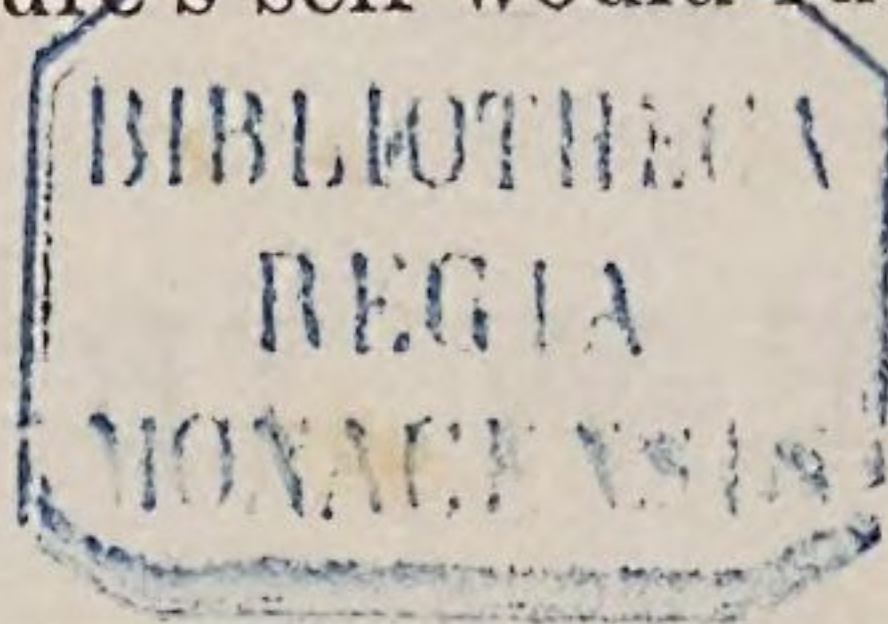
CONSERVATOR OF THE CONCHOLOGICAL SECTION OF THE ACADEMY OF NATURAL
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Each shell, each crawling insect holds a rank
Important in the plan of Him who framed
This scale of beings; holds a rank, which lost,
Would break the chain, and leave behind a gap
Which Nature's self would rue.



—STILLINGFLEET.

PREFACE.

THE admirable "Manual of the Mollusca," of the late S. P. Woodward, forms the basis of the present work; and in incorporating with it the numerous important acquisitions made by conchological science during the past twenty years, care has been taken to preserve its conservative spirit, as far as practicable.

The "Genera of Recent Mollusca," published by Messrs. Henry and Arthur Adams, in 1853-1858, introduced a large number of new generic and subgeneric groups, which experience has proved to be founded on unimportant or mutable characters. This work also, under the plea of priority of date of publication, substituted the vaguely-defined groups of obscure earlier writers for the more accurately described genera of Lamarck and his successors. The "Genera" certainly inaugurated the modern progressive era of systematic conchology; but, unfortunately, its vicious antiquarianism and free multiplication of genera revealed tempting opportunities to those desirous of obtaining the cheap distinction of naming new groups, or of overthrowing the names of old ones; so that for awhile the aim of many writers appeared to be scientific reputation, rather than the advance of knowledge. During the same period appeared Woodward's "Manual of the Mollusca;" and, probably, to that work, more than to any other influence, is due the gradual reaction towards a more stable classification.

An immense amount of reliable information is contained in the single 18mo volume of 486 pages, forming the first edition of Woodward (1851-1856); still, as the work was intended to

be more rudimentary in scope than that of the Messrs. Adams, many of the less important groups were insufficiently characterized or omitted. The Supplement published by Prof. Ralph Tate with the edition of 1870, included many additional genera, but scarcely represented the progress of the science to that date. Subsequent editions present no new features or additions.

Practically, more than twenty years have thus elapsed since the publication of an English text-book upon conchology; and for an almost similar period no treatise on the subject has appeared in any other country; yet these years have unquestionably been the most active in research and discovery of any in the history of the science. Dr. Kobelt, in Germany, Dr. Paul Fischer, in Paris, and myself, appear to have nearly simultaneously conceived the idea of supplying the want thus indicated.

Of Dr. Kobelt's work, now completed, it suffices to say that its elementary character makes it an introduction to, rather than a text-book of conchology. Dr. Fischer and myself have recognized the superiority of Woodward's Manual over every similar work heretofore published; and we have not only adhered generally to its plan, but largely copied from its pages.

Dr. Fischer's "*Manuel de Conchyliologie*," is in every respect an excellent work, well planned and abounding in original observations; and it promises, when completed, to become a worthy successor of "*Woodward*." Higher commendation could not be bestowed upon it. The first number of Dr. Fischer's "*Manuel*" appeared before I had definitely arranged the scope of my own similar undertaking; and at first I thought of abandoning the latter, to issue in its stead a translation of Fischer, with notes. But I had contemplated a work which, conservative as to genera, should nevertheless include, in a subordinate rank, the names and diagnoses of the numerous less well-marked or critical groups of modern authors; that is, these groups were to be included in more comprehensive ones, yet not extinguished.

Besides this, it had occurred to me that no conchological text-book, except translations of elementary works, had been published in this country; and that a work in which especial prominence should be given to the description and illustration of American genera would be found very useful by our students, as well as by many conchologists in other countries who are interested in American mollusks.

These designs I have decided to carry out in the present volumes. I have also aimed at more abundant illustration than is contained in the text-books referred to. The plates of this work will embrace nearly three thousand figures, mostly of good size, and sufficiently well-done to insure the recognition of the species. This feature has considerably increased the cost of the book, but will, I believe, fully recompense the purchaser for its necessarily increased price. Besides Woodward, I have availed myself fully of the large amount of valuable original material contained in the first parts of Dr. Fischer's "Manuel." My own time has been so engrossed by the study of systematic conchology, that the structural portion of my book is peculiarly indebted to Dr. Fischer; who, although an accomplished systematist, has mainly and very successfully occupied himself with anatomical investigations.

These general acknowledgments made, I have not deemed it necessary to designate by quotation-marks in the text all the paragraphs for which I am indebted to Messrs. Woodward and Fischer; but the authorities for numerous otherwise-derived statements and quotations are carefully recorded. The whole body of notes and references collated for my "Manual of Conchology," now in course of publication, has been examined for material. The "Structural and Systematic Conchology" may be considered an introduction and companion to that work. Constant and important aid in the preparation of the fossil genera has been rendered by my able colleague, Prof. Angelo

Heilprin, in charge of the invertebrate palæontological collection of the Academy of Natural Sciences of Philadelphia.

Having made such large acknowledgments, it is proper to acknowledge further that I cannot, on this occasion, properly claim the title of author; because there is very little herein contained originating with myself. The work is mainly a compilation; yet the selection and arrangement of material have been guided by experience, and if it should fail to realize reasonable expectations the responsibility for such failure must rest with

GEO. W. TRYON, JR.

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STRUCTURAL AND PHYSIOLOGICAL CONCHOLOGY.

PRIMARY DIVISIONS OF THE ANIMAL KINGDOM.

Every known animal appears to belong to one of eight principal types of structure, each of which is designated a subkingdom.

I. *Vertebrata*. The main mass of the nervous system is dorsal, protected and separated from the alimentary canal by a number of bony partitions, arranged consecutively in a single series and known as vertebræ.* From these vertebræ proceed ventral appendages termed ribs, enclosing the cavity of the body. The animal is bilaterally symmetrical, in its highest development provided with two pairs of limbs, anterior and posterior. The sexes are distinct. Each individual is developed from a single egg. Blood red.

II. *Malacozoa*. The nautilus, the common garden-snail, and the oyster, representatives of the three principal subdivisions of the mollusca proper, are familiar examples of this subkingdom. They are soft, fleshy animals, usually constructed with reference to the support of an external, hard, more or less enveloping shell, composed of carbonate of lime. Sometimes, in the cephalous mollusks, the shell is internal: that is, situated under the dorsal skin of the animal, and in such cases it is usually more simple in form, blade-like, or even reduced to a few calcareous granules. The internal shell, called "pen" of the squids certainly acts as a support to the animal in the same manner that the vertebral column does to man, but then it is not divided into segments, nor is it pierced by a spinal cord. Some cephalous mollusks are entirely without vestige of shell, either external or internal: in others the shell is horny instead of calcareous. The nervous system in the malacozoa consists of three or four pairs of ganglia, united by cords or commissures. The alimentary canal is encircled below the mouth by some of these ganglia and

* The "back-bone" is sometimes cartilaginous, and not divided into vertebræ. In *Amphioxus*, the most degraded of the vertebrate type, the circulation resembles that of the worms, the heart is wanting, the blood is colorless, there are no limbs: it appears to be a connecting link with the invertebrata—as all the succeeding subkingdoms are collectively designated.

their connectives, forming the œsophageal ring, whence proceed the principal cephalic nerves. Reproduction is oviparous usually, sometimes ovoviviparous.

In the Brachiopoda, the Tunicata and the Bryozoa the nervous system is more simple. These animals have usually been considered mollusks, but the two latter are now definitely excluded from the mollusca proper, whilst the former, despite structural and physiological affinities with the others, still receives the attention of Conchologists, mainly on account of its protecting bivalve shell. They together constitute a subdivision Molluscoida.

III. *Articulata*. Crabs, spiders and insects. The outer integument of the body is horny, composed of segments, bearing articulated locomotive members. The nervous system consists of pairs of ganglia arranged in the middle line of the body.

IV. *Vermes*. The body of worms is composed of segments, sometimes bearing non-articulated appendages. The nervous system varies; in the worms proper it is as complicated and similarly arranged to that of the articulates; in other forms it is reduced to a simpler structure. The digestive canal also varies: it has two orifices in the worms proper, the anus is wanting in the Planarians, and in the Cestoides and Acanthocephala there is no specialized alimentary tube.

V. *Echinodermata*. Star-fishes, sea-urchins, etc., sometimes called Radiata from their radiated structure. The animal is protected by an external shell or covering, sometimes calcareous. The nervous system consists of several trunks, which unite to form a ring around the mouth. The digestive tube is distinct from the visceral cavity: there is also a closed circulatory system.

VI. *Cœlenterata*. Coral animals, Actiniæ, Hydra, etc. In these the digestive apparatus is not specialized as in the Echinoderms but communicates or is confounded with the general cavity of the body. There is no closed circulatory system, and no nervous system has been detected except in some of the medusæ, where it is quite rudimentary.

VII. *Spongifera* or *Porifera*. The body-cavity is lined with vibratile cilia, which aid in expelling through its orifice the digestive products and eggs; this central cavity communicates through a system of afferent canals with the exterior, their outer openings representing multiple mouths.

VIII. *Protozoa*. Microscopic gelatinous animalcules, apparently without distinctive organs.

The above classification is modified from a well-known one of Prof. Huxley (though not his latest effort in this direction), and in the first subkingdoms agrees with the more ancient system of Cuvier. It is principally the Radiata of the distinguished

French naturalist that has been dismembered into distinct groups in consequence of our rapidly increasing knowledge of the diverse structure of these simpler forms of life. A comparison of the views of the most recent authorities, however, shows considerable divergence in their estimates of the systematic importance of structural peculiarities. Ray Lankester, for instance, admits no less than ten primary groups or subkingdoms below the mollusca. It matters little to the conchological student, however, whether some of the vermes be considered independent subkingdoms or not. Classification is necessarily based upon half-truths, because the values of structural differences are not demonstrably equivalent throughout, and because lines of affiliation co-exist with those of differentiation in most cases. Nature can only be artificially forced into the systematic relations of class, order, family, genus, etc. Still, these divisions have a conventional value, constantly varying according to the mental standpoint from which they are studied.

The Tunicata have been thought to form a connective link with the vertebrates through their most degraded member, Amphioxus, and Gegenbauer* makes them an independent "phylum" between Mollusca and Vertebrata; whilst E. Ray Lankester actually unites them with the latter group. The want of co-ordination of structural peculiarities in the so-called types of animals is, of course, considered important evidence for the development or derivative theory, and it has become fashionable to construct ancestral trees, bearing branches and leaves representative of the several animal types and their derivative relationships. As an example, Gegenbauer places Protozoa at the root of his tree, whence ascends a lateral, limbless trunk, terminating in Cœlenterata, whilst the main trunk rises vertically to Vermes, where it divides into branches bearing consecutively (from left to right), Mollusca, Vertebrata, Arthropoda, Brachiopoda, Echinodermata. Tunicata is a branchlet, proceeding from Vertebrata, and leaning towards Mollusca. The author of this structure speaks thus of his work: "These divisions represent in a general way separate branches of the pedigree of animals, and each of them contains higher and lower forms in various proportion. But the degree and extent to which their organization is developed is different in each of them. The divergence of organization expressed in each division is indicated by their relations to one another, and it shows us how the lower forms of the higher phyla may have started from the lower phyla."† It is sufficient, perhaps, to say here that the consanguinity indicated by the common characters of existing primary types, has not been in any

* Elements of Comparative Anatomy.

† Gegenbauer, Anat., 70.

appreciable degree strengthened by geological research; the earliest fossil vertebrate, mollusk or radiate being as clearly characteristic of its type as is its modern representative. It is only in the subordinate groups that we *know* differential characters to have developed from a common ancestral form.

The Vertebrates are usually spoken of as the highest form of animal existence, the Protozoa as the lowest; but it must be borne in mind that the one is as well fitted as the other to subserve the purposes of its life, that each in its organization is equally perfect. These terms, then, indicate complex and simple rather than perfect and imperfect organization.

CLASSES OF THE MALACOZOA.

True mollusks are broadly divided into two great groups by important external characteristics :

1. *Encephala*. The animal possesses a head, and is usually protected by a spiral shell. Example, the snail.

2. *Acephala*. The animal is without a head, and is always protected by a shell consisting of two pieces applied to its sides, and connected at the back by a ligament or hinge. Example, the oyster.

To these two divisions are also familiarly applied names describing the nature of their shelly coverings; the first being known as univalves, the last as bivalves. These designations are partially incorrect and insufficient, as we shall soon see; but as the collection, preservation and study of shells is made with facility, whilst the animals or soft parts are more difficult to obtain and preserve, the former have imposed upon us a designation which may be well enough understood but is scarcely correct; it would be preferable to call our science Malacology, the study of molluscous or soft animals, yet it is almost universally known as Conchology, the Science of Shells.

I. ENCEPHALA.

Herein are included more than three-fourths of the whole number of molluscous animals including four out of the five classes into which the mollusca proper are divided. These classes take their names from and are primarily founded upon their respective locomotive organs.

Class I. Cephalopoda. Cuttle-fish, argonauts, and their allies, so called from the circle of feet, or more properly arm-like limbs enclosing the mouth and arising from the top of the head (Pl. xxiii).

Class II. Pteropoda. Animals inhabiting the high seas, swimming by means of a pair of wings, extending laterally from the back of the head. Clio, Hyalæa, etc. (Pl. xlii).

Class III. Gastropoda or snails. The under side of the body forms a muscular foot, suitable for gliding (Pl. xviii, f. 16).

Class IV. Scaphopoda. Head rudimentary. Foot vermiform, furnished with lobes. A degraded form of the encephala having relationships with Vermes, one of the most obvious of which is its shell, a hollow cylinder open at both ends, the spiral shell of the gastropod unrolled into a tube, reduced to the last degree of simplicity in form.

The shell, when present in the Encephala, is usually external and spiral, as in the helix, the whelk, nautilus, etc., but there are notable exceptions in all the classes :

In the Cephalopoda a whole order (Octopoda) is mostly without any shell, whilst another order (Decapoda) is mostly furnished with a simple shell called a pen, developed beneath the dorsal skin. Very few species of recent cephalopods have an external spiral shell, but during the earlier geological periods thousands of species of such animals existed.

In the pteropods (sometimes considered an order of Gastropoda) the shell is glassy ; globular, conical, cylindrical or spiral, but is often wanting.

In the Gastropoda the shell is usually external and spiral, but sometimes tubular or even reduced to a low cone, the point of which is the beginning of its growth, the large end the mouth or aperture. Sometimes the shell is internal ; occasionally internal and rudimentary, consisting of an irregular calcareous plate or several grains, and frequently altogether absent. Portions of this class are terrestrial or fluviatile, but most of its species are marine : the other classes of encephala are strictly marine animals.

The Chiton or coat-of-mail shells form an aberrant group, the shell consisting of eight distinct calcareous plates, usually overlapping, and lodged in a coriaceous skin or mantle.

In the Scaphopoda or Solenoconcha (dentalia or tooth shells) the shell is external and tubular.

All the Encephala are provided with a tongue or lingual ribbon, the superior surface of which usually bears rows of teeth used in rasping their food ; many have also plates, called jaws, lodged within the mouth, and aiding in comminuting food. The cephalopods have external horny beaks, suitable for cutting or tearing. None of these organs are found in the Acephala.

II. ACEPHALA.

This term is frequently used as synonymous with the single class which it contains.

Class V. Pelecypoda, Lamellibranchiata or *Conchifera* (Pl. iii). The bivalve mollusca are familiarly represented by the oyster, clam, mussel, etc. The name *Lamellibranchiata* is more

usually applied to these mollusks and refers to the breathing organs, consisting of a pair of flat, membranous gills attached to the mantle. Pelecypoda is a preferable designation for the sake of uniformity with the class names in the Encephala and inasmuch as, in the cephalopods and gastropods, the next subsidiary division into *Orders* is distinguished by names indicating differences in the breathing organs. Both the breathing and locomotive organs (the latter rudimentary) restrict this class to an aqueous life: they are marine and fluviatile in distribution. The shell is generally in two pieces symmetrically applied to the sides of the animal, but there are, in one of the orders, small accessory pieces, plates or valves applied upon or on the sides of the hinge line.

Anciently shells were grouped into univalves, bivalves and multivalves, and the latter included the chitons (gastropods) the pholades (pelecypods), as well as certain lepades (crustaceans), etc.

The Molluscoida include the Brachiopoda, Tunicata and Bryozoa. The reciprocal relations of these groups scarcely justify their union as classes under this head, whilst on the other hand their individual characteristics are not sufficiently important to give them each the same systematic value as mollusca.

Class I. Brachiopoda are covered with a bivalve shell, the valves of which are placed dorsally and ventrally instead of being applied to the sides of the animal, as in Pelecypoda. The name is derived from two long ciliated organs developed from the sides of the mouth, which were originally termed arms—whence the term *arm-footed*; they are, however, breathing organs, and Brachionobranchia has been proposed as a more correct designation, but will scarcely obtain the preference over the shorter name so long in use.

Class II. Tunicata. Instead of a shell the tunicates are protected by an elastic integument, formed of cellulose, and having two orifices—mouth and anus. An inner sack with numerous openings forms the breathing organ, and the nervous system consists of a single ganglion placed near the mouth.

Class III. Bryozoa or Polyzoa, are microscopic animals, each protected by a calcareous or chitinous shell: they live in colonies, attached, and their aggregated shells form coralline incrustations upon the surface of molluscous shells or other marine or fluviatile objects.

Only one of the classes of Molluscoida will be included in this work. The brachiopods have so long been considered true mollusca, their shells are so similar to those of the Pelecypoda, they occur together, and have so occurred from an early geological period, so that practically they continue to be as much

the objects of the Conchologist's investigation as they were before their somewhat diverse nature was ascertained.* The Tunicata and Bryozoa, on the contrary, have never received much attention from Conchologists, the first because they could only be preserved in spirits and thus were inaccessible to most students, the last because their microscopic size and their aggregation into encrusting colonies caused them at first to be considered of much simpler organization than modern investigation has proven to be the case.

The classes of the malacozoa may be tabulated as follows :

MALACOZOA.

A. MOLLUSCA.

a. Encephala.

Class 1. Cephalopoda.

Class 2. Pteropoda.

Class 3. Gastropoda.

Class 4. Scaphopoda.

b. Acephala.

Class 5. Pelecypoda.

B. MOLLUSCOIDA.

Class 1. Brachiopoda.

Class 2. Tunicata.

Class 3. Bryozoa.

The systematic arrangement of natural objects, says Woodward, ought not to be guided by convenience, nor framed merely for the purposes of easy remembrance and communication. The true method must be suggested by the objects themselves, by their qualities and relations;—it may not be easy to learn, it may require perpetual modification and adjustment—but inasmuch as it represents the existing state of knowledge, it will aid in the understanding of the subject, whereas a dead and arbitrary arrangement is a perpetual bar to advancement, containing in itself no principle of progression.

* The acceptance of the view originally propounded by Steenstrup and so ably urged by Professor Morse, respecting the affinities of the brachiopods with the worms (Proc. Bost. Soc. Nat. Hist., 1873), does not to my mind weaken the opinion I have always held as to their affinities with the Polyzoa (Bryozoa). on the one hand, and with the higher mollusca on the other."—*Huxley, Anat. of Invert. An.*, 468.

ANATOMY OF THE MOLLUSCA.

EXTERNAL FEATURES.

The CEPHALOPODA are immediately distinguished from all other classes of the mollusca by the circle of *acetabula* or *arms* (xxiii), which surrounds the head; these were formerly regarded as homologous with the foot of the gastropods, with its margins produced into the eight or ten processes which are indifferently designated as arms, acetabula or brachia, but the *siphon* (xxiii, 9), is more largely used as an organ of locomotion than are the arms, and its ventral position, as well as the distribution of the nerves, indicate that it, rather than the arms, is the homologue of the foot of the gastropod.

The mouth is supplied with a pair of calcareous or horny jaws, resembling in form the beaks of a parrot (ix, 93, 95). The arms proper, in the naked cephalopods, are eight in number, and are distinctively called sessile arms, to distinguish them from the *tentacular arms* or tentacles, much longer, and capable of retraction within pouches, which are additionally possessed by those species which have an internal shell or cuttle-bone. The sessile arms are provided with suckers (xxiii, 4), or hooks for prehension, covering their internal surface, whilst the tentacles are expanded into club-shaped terminations similarly armed (xxv, 20). In the Nautilus, sole living representative of an exceedingly numerous extinct order, the arms degenerate into numerous tentacles (iv, 62, 63), unarmed, which are retractile into eight sheaths, morphologically representing the typical eight arms. In this animal only, the body is contained within, and protected by, an external shell, which compensates to it the loss of the offensive and locomotive powers possessed by its more highly organized allies.

Behind the arms, the circle of which may constitute its crown, that major portion of the head is situated which is usually distinctively so designated; its dorsal aspect exhibits on either side an eye. The head may be joined to the body by a more or less constricted neck, or is frequently sessile upon the latter, without intervening constriction. The body, or mantle, is dorsally more or less continuous with the head, but ventrally forms a sack anteriorly open, and from which emerges the funnel or siphon. The sack or body is, in a small portion of the octopod and in the decapod species, expanded into postero-lateral membranes, possessing the power of undulatory motion, and which may be considered as the equivalent of fins, in function, though not in appearance.

The body in the GASTROPODA presents the following more or less differentiated portions:

1. *Head*. This is sometimes partially separated from the body by an intervening constriction or neck, but is very frequently only indicated by the possession of a mouth on its ventral and of a pair of tentacles on its dorsal surface. From the latter sometimes proceed pedicels bearing the eyes.

2. *Mantle*. This covers the posterior portion of the dorsal surface of the body.

3. *Foot*. The ventral surface of the body, or a specialized portion of it.

The *mouth* may be either simple, in the plane of the head, or it may be produced at the end of a contractile *rostrum*, or of a retractile *proboscis* (xvi, 91). Behind the head and on the under side of what may be called the *neck* is attached the foot, and behind the neck begins the posterior portion of the body covered by the mantle; this part of the animal is very long, usually, and as the shell is moulded upon it, it assumes a similar form—generally spiral. However, in *Patella* and similar limpet-like shells, the body is short and straight. The mantle encircles the body like a *collar* below, but above it is much produced over the back of the animal, and the respiratory cavity forms a *sinus* of its margin. The foot consists of the attachment to the neck, which is usually narrow, and an expanded portion, sole, or creeping disk. Such is its typical form, but in *Patella*, etc., the foot includes the entire ventral surface of the animal. It is a muscular process of the body, and the only locomotive organ possessed by gastropods.

Viewed externally, gastropods, as well as the mollusca in general, must be regarded as bilaterally symmetrical; a view which is strengthened by the position of the nervous system, and the developmental history of the intestines: though their actual position, as well as that of the sexual organs, does not correspond with this symmetry. Thus we find that at first the *anus* is at the posterior end of the body, but gradually it approaches nearer and nearer to the anterior end until finally it opens on the back or right side near the mouth. In its early stages the shell and mantle only occupy the extreme posterior end of the body, but in their growth they cover more and more of the latter, gradually pushing the anus forward.

An external shell, usually sufficiently large to contain the entire animal, is common to most Gastropoda. It is a secretion of the mantle, and conforms to its shape; and the hardness which it assumes by the addition of carbonate of lime, renders it an efficient protection to the animal, whilst the faithfulness with which it reproduces the external features of the latter renders it extremely useful in classifying the mollusca. The spiral growth of shells is as nearly of true mathematical regularity as is possible in an organic body; forming the loga-

rithmic spirals of Moseley, or conchospiral of Naumann. Corresponding to the shell, which is produced by the mantle, and borne by the posterior portion of the body, the posterior dorsal part of the foot bears an operculum, secreted by an expansion of its skin called the *opercular mantle*. Typically, the operculum is a spiral also, but in the same plane; yet in many cases its growth is annular. Usually horny, it is sometimes entirely or partially calcareous, and on the retirement of the animal within the shell it is brought into the aperture of the latter, which it more or less completely closes. Like the shell itself, it may be considered a protective organ, and when in apposition with the former suggests the two enclosing valves of the lamellibranchiate or bivalve mollusks.

Notwithstanding the large portion of the animal which is always within the shell, even when the head and foot are extruded, the latter is only attached to the former at one point, on the columella, and by means of a columellar muscle, which, passing through the foot, is attached at its other end to the operculum (when the latter is developed, which is not always the case). Although there is only this single actual bond of connection between shell and animal, the contact of the body serves to maintain the vitality of the shell, which soon bleaches, and finally decays when separated from its architect and inhabitant.

The Pelecypoda (xxii) differ from the preceding two great classes of the Mollusca in having no specialized head, though provided with a mouth, organs of sight, etc. The foot is a fleshy process adapted by its form to digging rather than to locomotion. The *gills*, arranged on either side the body, the enclosing valves of the testaceous covering, which are united by a hinge dorsally or at their initial point, the arrangement of those organs which are not paired in the median plane of the body—all show that the bivalve mollusk is symmetrical; although in certain attached genera the intestines are crowded into the lower side or valve, the cavity of the valve uppermost in position being usually very shallow.

The security against many enemies which their completely enveloping bivalve shell affords the pelecypoda, and the great proportionate weight of this testaceous covering have tended to produce in these animals a much less active existence than that of the encephala; their movements are slow usually, and the adults of the *attached* families, such as *Spondylus*, *Ostræa*, etc., remain for life in one position without possessing the power of changing their residence. The food of the pelecypoda cannot be said to be sought for, but is simply selected from such vegetable and minute animal organisms as the water may float within reach of their mouths. These generally sluggish habits,

with the absence of externally apparent differentiation of parts, organs, or members, has caused the expression "Stupid as an oyster" to be applied to them—an undeserved imputation, as we shall find even the attached oyster, one of the simplest organized of the bivalve mollusca, is well furnished with organs suitable not only for the support, but even for the enjoyment of its placid life—hid though most of these are beneath its enveloping skin or mantle.

THE SKIN.

The epithelium in the dibranchiate cephalopods, is composed of flask-like or rounded grain-like cells; they are cylindrical in *Nautilus*. Under this lies a thin fibrous layer, which again covers that containing the chromatophores. The skin of the cephalopod, particularly its dorsal surface, is covered with apparently minute specks of a dark reddish color; these are *pigment cells* or *chromatophores* (iv, 60, 61), each provided with radiating muscles, by which, at the will of the animal, the little sacks are greatly dilated, and the color becomes intensified. The rapid chameleon-like changes of color peculiar to the cephalopoda among mollusca, are thus produced; whilst the accompanying opal-like and silvery appearance exhibited by the cuttle-fishes, is due to a thin layer underlying the pigment layer, and reflecting through it. In the tentacles of *Nautilus* are found epithelial pigment cells, which, according to Rumphius, are used similarly to the chromatophores.

The outer skin, in many of the genera, is furnished with contractile tubercular elevations or *beards*, which are raised when the animal is irritated, and give it a rather ferocious appearance. These beards are disposed in symmetrical patterns, upon the dorsal surface, and particularly around the eyes, and their number and position form distinctive characters of the species.

It will be readily understood, from the above, that color is scarcely characteristic of species in the Cephalopoda. The littoral species of *Octopus*, etc., which ordinarily await their prey, instead of pursuing it like the finned pelagic species, seem to possess and exercise to some extent through their chromatophores, a power of color mimicry.

The body in the Gastropoda is also completely enveloped by an external more or less elastic skin (iii, 44). Its epithelial layer is formed of quadrangular or prismatic cells, which have a distinct nucleus, and occasionally, when long-cylindrical in form, they have a tail-like end beneath, penetrating the cutis. (Possibly these last are epithelial terminations of nerves—hence sense organs.) Externally the epithelium sometimes supports cilia upon the exposed portions of the body.

The cutis consists essentially of fine interlacing muscular fibres with interposed cells; often attaining a perceptible thickness. The subcutaneous muscular layers of the body are immediately continuous with those of the cutis: the fibres of which they are formed may be clearly distinguished as an outer longitudinal and inner circular layer. These fibres are (as in mollusks generally) compressed and band-like, with pointed ends and central oval nucleus.

In *Doris* (iii, 39) and some other opisthobranchiates the skin is consolidated and rendered rigid by a number of calcareous spiculæ, which have a somewhat definite arrangement and form a sort of internal skeleton. In *Paludina* these spicules are replaced by globulous calcareous concretions, in *Pholas* by siliceous granules. Chalky scales from the cephalopod *Scæurgus titanops* are represented, greatly magnified, by fig. 59, Pl. iv.

The skin forms a fold above and surrounding the foot, and this portion is technically termed the *mantle*; it surrounds the body, behind the cephalic portion like a *collar*, and thence spreads dorsally over the posterior part of the animal. In the terminal, thickened border of the mantle, the cutis becomes of greater thickness; its upper stratum containing very numerous glands, furnishing the mucus and colors which are here mingled with the secreted shell-material. Similar glands, furnishing a copious supply of mucus, are found also in the cephalic portion of the body as well as in the foot, and especially in the sole; but no cells are found in that part of the animal permanently covered by the shell. Frequently, the external skin is colored by a granular pigment, which either is contained in cells, lying between or enveloping the glands, or else sometimes appears to lie free under the epithelium.

The mantle border is the principal agent in the secretion of the shell; it is thrown out by the epithelial layer as a sort of cuticular development. With the organic basis of this secretion is mingled carbonate of lime, originating in the epithelial cells, where it may be separated from the blood; in hardening, the exuded material becomes half crystalline or laminated. Usually the external layer of the shell is a transparent or translucent skin, the epidermis; having no lime in its composition. It is often colored by pigments lying in the outermost border of the mantle.

Whilst the growth of the shell is thus provided for by additions to the aperture margin from the mantle border, the whole mantle is equally capable of producing shelly substance; and not only are shells thus thickened from within by the mantle surface, but breaks are repaired with new material by a similar provision: such repaired and interior portions are devoid of epidermis and of color, the pigments being found only in the free border of the

mantle. Mollusks are even able to secrete shelly matter to provide against threatening dangers from the boring of other animals into their shell. A curious example of shell secretion by the visceral mantle occurs in a cone belonging to the cabinet of the late Dr. Gray. A section of this shell has been made, showing holes bored into the spire end by lithodomi and the repeated walls erected by the animal across the ends of the whorls to protect itself against the ravages of its insidious enemies (i, 8).

The mantle border by means of its sphincter muscles embraces the body closely, thus closing the mantle cavity except at one point, where a small opening allows the ingress and egress of water for respiration. This respiratory opening is a semicircular notch, formed by muscles, and is sometimes prolonged on its dorsal wall into a half-closed tube or respiratory *siphon* (xvi, 89), which, when present, assists by the phases of its development in the classification of the mollusca. This siphon usually forms an anterior notch in the shell near the margin of the columella and the existence of the latter thus predicates that of the former. The siphonal tube is sometimes greatly prolonged, and is then frequently covered for most or all its length by a prolongation of the aperture, which is technically known as the canal of the shell. The canal in *Murex* and *Fusus* is extremely long, at least in the typical species. Mollusks of which the shells are furnished with a canal or anterior notch are called *siphonostomata*, the first great division of the prosobranchiate gastropods. The siphon is principally confined to predatory or carnivorous mollusks. In the second great division, termed *holostomata*, the shells have rounded apertures; consequently no siphon but simply an opening for respiration. They are vegetable feeders usually (*Natica* is a remarkable exception), and close the aperture of the shell completely by an operculum.

At the posterior left border of the mantle, behind the branchiæ, is sometimes an opening from which a small siphon extends backwards, and when it is present, it forms a notch in the posterior part of the shell, as in *Cypræa* and *Conus*, or a canal as in *Ovula*, (lxi), or frequently it only forms a callosity on the upper part of the columella, close to its junction with the posterior part of the aperture margin. This siphonal opening serves for the exit of the water that has entered by the branchial opening.

The mantle border can usually be freely withdrawn within the whorl, as it is not united to the shell at any point. It is frequently prolonged into digitations, or exhibits prominences or invaginations, all of which develop similar features on the shell; thus giving rise to the fingers of *Pteroceras*, the spines of *Murex*, etc. Occasionally, however, processes of the mantle do not secrete shelly coverings (iii, 45). *Cerithium* and the oriental

Melanians, for instance, have delicately digitated mantle margins, these digitations forming no secretion, and sometimes thrown back over the shell.

The mantle is occasionally largely developed into side lobes which in *Marginella* and *Cypræa* are so extended as to be habitually thrown up over the external surface of the shell, nearly or completely covering it: in such shells an epidermis is not present. The mantle lobes of *Cypræa* are beset with numerous papillæ, which seem to partake the function of tentacles as tactile organs (lxi, 99). In other genera, as in *Oliva*, the mantle is prolonged into filiform processes before and behind (iii, 46).

The female *Vermetus* has the mantle cleft in the middle, according to Lacaze-Duthiers, although there is no corresponding cleft in the shell, and in *Haliotis* a similar mantle cleft impresses a groove in the shell, in which are situated the row of holes characteristic of the genus. The shell of *Pleurotoma* also has a sinus corresponding to a cleft mantle. The cause of the sutural sinus of the shell of the American freshwater genus *Schizostoma* is as yet unknown; it may be due to a similar cause or it may be sexual. As the genus is restricted to the Coosa River and its neighborhood, I am inclined to think that it is a local disturbance of growth, especially as most of the species could not be distinguished from corresponding forms of *Goniobasis* except by the lip notch or slit.

The velum or natatory organ is a temporary lobe of the skin, developed in the larval forms of certain gastropods as well as in pelecypods (xx, 52).

The skin in the latter class is usually smooth, except that the foot in certain boring species develops siliceous granules. The double siphons are parallel prolongations of the mantle margin in certain bivalve mollusks, the superior siphon being excretory, and the inferior one for inspiration (iii, 50).

THE SHELL.

The relation of the shell to the breathing organ is very intimate: indeed, it may be regarded as a *pneumo-skeleton*, being essentially a calcified portion of the mantle, of which the breathing organ is at most a specialized part. In its most reduced form it is only a hollow cone, or plate, protecting the breathing organ and heart, as in *Limax*, *Testacella*, *Carinaria*. Its peculiar features always relate to the condition of the breathing organ; and in *Terebratula* and *Pelonaia* it becomes identified with the gill. In the nudibranchs the vascular mantle performs wholly or in part the respiratory office. In the cephalopods the shell becomes complicated by the addition of a distinct, internal,

chambered portion (phragmocone), which is properly a visceral skeleton; in *Spirula* the shell is reduced to this part.

The shell is so characteristic of the mollusca that they have been commonly called "testacea" (from *testa*, "a shell") in scientific books; and the popular name of "shell-fish," though not quite accurate, cannot be replaced by any other epithet in common use. In one whole class, however, and in several families, there is nothing that would be popularly recognized as a shell.

The study of the shell is of great zoological importance, as its form and composition vary characteristically in the different genera; and it becomes still more important geologically, inasmuch as it is almost the only portion of the vast number of fossil species which has been preserved to us; and by the study of it in comparison with recent species, we are enabled not only to distinguish the species and genera of these extinct forms, but even to predicate the external appearance, the anatomy, the physiology of the animals, with nearly the accuracy with which the vertebrate palæontologist reconstructs a mammal or a reptile from its osseous fragments.

Shells are said to be *external* when the animal is contained in them, and *internal* when they are concealed in the mantle; the latter, as well as the shell-less species, being called *naked* mollusks.

Three-fourths of the mollusca are *univalve*, or have but one shell; the others are mostly *bivalve*, or have two shells; the Pholads have accessory plates, and the shell of *Chiton* consists of eight pieces. Most of the *multivalves* of old authors were articulate animals (cirripedes), erroneously included with the mollusca, which they resemble only in outward appearance.

All, except the Argonaut, acquire a rudimental shell before they are hatched, which becomes the *nucleus* of the adult shell; it is often differently shaped and colored from the rest of the shell, and hence the *fry* are apt to be mistaken for distinct species from their parents.

In *Cymba* (i, 15), the nucleus is large and irregular; in *Fusus antiquus* it is cylindrical; in the Pyramidellidæ it is oblique; and it is spiral in *Carinaria*, *Atlanta*, and many limpets, which are symmetrical when adult.

The rudimentary shell of the nudibranchs is shed at an early age, and never replaced. In this respect the molluscan shell differs entirely from the shell of the crab and other articulate animals, which is periodically cast off and renewed.

In the bivalves the embryonic shell forms the *umbo* of each valve (ii, 31); it is often very unlike the after-growth, as in *Unio*, *Cyclas*, and *Hinnites*. In attached shells, like the oyster and

Anomia, the umbo frequently presents an exact imitation of the surface to which the young shell originally adhered.

Shells are composed of carbonate of lime, with a small proportion of animal matter. The source of this lime is to be looked for in their food. Modern inquiries into organic chemistry have shown that vegetables derive their elements from the mineral kingdom (air, water, and the soil), and animals theirs from the vegetable. The sea-weed filters the salt water, and separates lime as well as organic elements; and lime is one of the most abundant mineral matters in land plants. From this source the mollusca obtain lime in abundance, and, indeed, we find frequent instances of shells becoming unnaturally thickened through the superabundance of this earth in their systems. On the other hand, instances occur of thin and delicate-shelled varieties in still, deep water, or on clay bottoms; whilst in those districts which are wholly destitute of lime, there are no mollusca. Helices sometimes form cavities in limestone rocks, and M. Bouchard-Chantereaux supposes the foot of the animal to exude an acid solvent which effects the excavation; but Dr. Fischer shows that the jaw and tongue only are probably employed for this purpose, and that the material excavated is used in the formation of shell by the animal. So imperious is the necessity for this material, that Limnæans brought up in captivity, devour the shells of their companions in order to obtain it. M. Gassies, who has raised many terrestrial mollusks, never fails to place pieces of limestone in their cages, and these are eroded more or less rapidly by the needs of the growing Helices. Omitting to provide the limestone, the growth of the shell is retarded or arrested.

The texture of shells is various and characteristic. Some, when broken, present a dull lustre like marble or china, and are termed porcellanous; others are pearly or nacreous; some have a fibrous structure; some are horny, and others glassy and translucent (i, 1).

The nacreous shells are formed by alternate layers of very thin membrane and carbonate of lime, but this alone does not give the pearly lustre, which appears to depend on minute undulations of the layers (i, 2). This lustre has been successfully imitated on engraved steel buttons. Nacreous shells, when polished, form "mother-of-pearl;" when digested in weak acid they leave a membranous residue which retains the original form of the shell. This is the most easily destructible of shell-textures, and in some geological formations we find only casts of the nacreous shells, whilst those of fibrous texture are completely preserved.

Pearls are produced by many bivalves, especially by the Oriental pearl-mussel *Avicula margaritifera* (i, 9), and one of

the common river mussels (*Margaritana margaritifera*). They are also found occasionally in the common oyster, in *Anodonta*, *Unio*, *Pinna nobilis*, *Mytilus edulis*, or common mussel, and in *Spondylus gæderopus*. In these they are generally of a green or rose color. The pearls found in *Arca Noë* are violet, and in *Anomia cepa* purple. They are similar in structure to the shell, and, like it, consist of three layers; but what is the innermost layer in the shell is placed on the outside in the pearl. The iridescence is due to light falling upon the out-cropping edges of partially transparent corrugated plates. The thinner and more transparent the plates the more beautiful is the iridescent lustre; and this is said to be the reason why sea pearls excel those obtained from fresh-water mollusks. Besides the furrows formed by the corrugated surface there are a number of fine dark lines ($\frac{1}{7700}$ inch apart), which may add to the lustrous effect. In some pearls these lines run from pole to pole like the longitudes on the globe; in others they run in various directions; and in a few the lines on the same pearl have different directions, so that they cross each other. The nucleus frequently consists of a fragment of a brownish-yellow organic substance, which behaves in the same way as epidermis when treated with certain chemical reagents. Sand is generally said to be the nucleus; but this is simply a conjecture which has gradually become regarded as a fact; it is quite the exception for sand to be the nucleus; as a general rule it is some organic substance. In some districts one kind of nucleus seems to be more common than another; at least, this is how the different results obtained by observers in different localities may be explained. Filippi (*Sul' origine delle Perle*, translated in Müller's *Archiv*, 1856) found the parasitic helminth *Distoma* to be the nucleus in many *Anodontas*; Kuchenmeister found that the pearls were most abundant in the mollusks living in the still parts of the River Elster, where the water-mites (*Limnochares anodontæ*) existed most numerously. The most generally prevalent nucleus appears to be the bodies or eggs of minute internal parasites, such as *Filaria*, *Distoma*, *Buchephalus*, etc. Completely spherical pearls can only be formed loose in the muscles or other soft parts of the animal. The Chinese obtain them artificially by introducing into the living mussel foreign substances, such as pieces of mother-of-pearl fixed to wires, which thus become coated with a more brilliant material. The relief figures of idols in pearl which ornament the interior of Chinese species of *Dipsas* (i, 10) are a deposit of nacreous material made upon metal forms introduced between the shell and mantle; they are produced in about a year. The manufacture of pearls is a large industry in China; the process was discovered by a native of Hutcheifu in the thirteenth century. European

attempts to procure pearls in this manner have not been financially successful.

Similar prominences and concretions—pearls which are not pearly—are formed inside porcellaneous shells; these are as variable in color as the surfaces on which they are formed.

The fibrous shells consist of successive layers of prismatic cells containing translucent carbonate of lime; and the cells of each successive layer correspond, so that the shell, especially when very thick (as in the fossil *Inoceramus* and *Trichites*), will break up vertically into fragments, exhibiting on their edges a structure like arragonite, or satin-spar. Horizontal sections exhibit a cellular network, with here and there a dark cell, which is empty (i, 3).

The oyster has a laminated structure, owing to the irregular accumulation of the cells in its successive layers, and breaks up into horizontal plates.

In the boring-shells (*Pholadidæ*) the carbonate of lime has an atomic arrangement like arragonite, which is considerably harder than calcareous spar; in other cases the difference in hardness depends on the proportion of animal matter and the manner in which the layers are aggregated.

In many bivalve shells there occurs a minute tubular structure, which is very conspicuous in some sections of *Pinna* and oyster-shell. This tubular structure is frequently occasioned by the growth of a confervoid sponge, hence great care is required in determining whether the perforations are an essential part of the shell.

The Brachiopoda exhibit a characteristic structure by which the smallest fragment of their shells may be determined; it consists of elongated and curved cells matted together, and often perforated by circular holes, arranged in quincunx order (i, 5).

But the most complex shell-structure is presented by the porcellaneous Gastropoda. These consist of three strata which readily separate in fossil shells, on account of the removal of their animal cement (i, 6, 7). Each of these three strata is composed of very numerous vertical plates, like cards placed on edge; and the direction of the plates is sometimes transverse in the central stratum, and lengthwise in the outer and inner (as in *Cypræa*, *Cassis*, *Ampullaria*, and *Bulimus*), or longitudinal in the middle layer and transverse in the others (*e. g.* *Conus*, *Pyrula*, *Oliva*, and *Voluta*).

Each plate, too, is composed of a series of prismatic cells, arranged obliquely (45°), and their direction being changed in the successive plates, they cross each other at right-angles. Tertiary fossils best exhibit this structure, either at their broken edge, or in polished sections.

The argonaut-shell and the bone of the cuttle-fish have a

peculiar structure; and the Hippurite is distinguished by a cancellated texture, unlike any other shell, except perhaps some of the Cardiaceæ and Chamaceæ.

Epidermis. All shells have an outer coat of animal matter called the "epidermis" (or *periostracum*), sometimes thin and transparent, at others thick and opaque. It is thick and olive-colored in all fresh-water shells and in many Arctic sea-shells (*e. g.* *Cyprina* and *Astarte*); the colors of the land-shells often depend on it; sometimes it is silky as in *Helix sericea*, or fringed with hairs as in *Trichotropis*; in the whelk and some species of *Triton* and *Conus* it is thick and rough, like coarse cloth, and in some *Modiolas* it is drawn out into long beard-like filaments.

In the cowry and other mollusks with large mantle lobes the epidermis is more or less covered up by an additional layer of shell deposited externally.

The epidermis has life, but not sensation, like the human scarf-skin; and it protects the shell against the influence of the weather and chemical agents; it soon fades or is destroyed after the death of the animal in situations where, whilst living, it would have undergone no change. In the bivalves it is organically connected with the margin of the mantle.

It is most developed in shells which frequent damp situations, amongst decaying leaves, and in fresh-water shells. All fresh waters are more or less saturated with carbonic acid gas, and in limestone countries hold so much lime in solution as to deposit it in the form of tufa on the mussels and other shells. But in the absence of lime to neutralize the acid the water acts on the shells, and would dissolve them entirely if it were not for their protecting epidermis. As it is, we can often recognize fresh-water shells by the erosion of those parts where the epidermis was thinnest, namely, the points of the spiral shells and the umbones of the bivalves, those being also the parts longest exposed. Specimens of *Melanopsis* and *Bithynia* become truncated again and again in the course of their growth, until the adults are sometimes only half the length they should be, and the discoidal *Planorbis* sometimes becomes perforated by the removal of its inner whorls; in these cases the animal closes the break in its shell with new layers. Some of the *Unios* thicken their umbones enormously, and form a layer of animal matter with each new layer of shell, so that the river action is arrested at a succession of steps.* But the action of an acid is certainly not the only cause of erosion; it is assisted by the ravages of various boring animals in some cases, and is frequently largely

* On erosion of fluviatile shells, see Dr. James Lewis, Bost. Soc. Proc., vi, 149.

caused by the wants of the mollusks themselves, which in waters not sufficiently charged with lime are compelled to devour the unoccupied and unprotected parts of their neighbors' houses to obtain material for the enlargement of their own.*

Formation and Growth of the Shell. The shell, as before stated, is formed by the mantle; indeed, each layer of it was once a portion of the mantle, either in the form of a simple membrane or as a layer of cells; and each layer was successively calcified (or hardened with carbonate of lime) and thrown off by the mantle to unite with those previously formed. Being extravascular it has no inherent power of repair.

The epidermis and cellular structures are formed by the margin (or collar) of the mantle; the membranous and nacreous layers, by the thin and transparent portion which contains the viscera; hence we find the pearly texture only as a lining inside the shell, as in the Nautilus, and all the Aviculidæ and Turbinidæ.

If the margin of a shell is fractured during the lifetime of the animal, the injury will be completely repaired by the reproduction both of the epidermis and of the outer layer of shell with its proper color. But if the apex is destroyed, or a hole made at a distance from the aperture, it will merely be closed with the material secreted by the visceral mantle. Such inroads are often made by boring worms and shell, and even by a sponge (*Cliona*), which completely mines the most solid shells.

Lines of Growth. So long as the animal continues growing, each new layer of shell extends beyond the one formed before it; and, in consequence, the external surface becomes marked with lines of growth. During winter, or the season of rest which corresponds to it, shells cease to grow; and these periodic resting-places are often indicated by interruptions of the otherwise regular lines of growth and color, or by still more obvious signs. It is probable that this pause, or cessation from growth, extends into the breeding season; otherwise there would be two periods of growth and two of rest in each year. In many shells the growth is uniform; but in others each stage is finished by the development of a fringe, or ridge, *varix* (xlv, 54, 55), or of a row of spines, as in *Tridacna* and *Murex*.

Adult Characters. The attainment of the full growth proper to each species is usually marked by changes in the shell.

Some bivalves, like the oyster and *Gryphæa*, continue to increase in thickness long after they have ceased to grow outwards; the greatest addition is made to the lower valve, especially near the umbo; and in the *Spondylus* some parts of the mantle

* *Fischer, Actes Linn. Soc. Bord.*, xviii.

secrete more than others, so that cavities, filled with fluid, are left in the substance of the shell.

At maturity the *Teredo* and *Fistulana* close the extremity of their calcareous tubes completely, whilst the *Aspergillum* closes its tube with its characteristic porous or sieve-like disk. The genera of *Jonannetinae*, near allies of the above remarkable bivalves, have in youth a largely developed foot, but at maturity this organ undergoes a retrogressive metamorphosis, becomes atrophied, and is closed in by a calcareous deposit which connects the originally gaping shelly valves into a closed club-shaped tube. Other bivalves, as the symphynote *Unios* and *Pinna*, solder their dorsal line or a portion of it so that continued motion of the valves would be impossible, only that in the first a rupture of one of the soldered wings takes place near its base, so that one of the valves carries both wings whilst the adductors have recovered their power. In *Pinna* the elasticity of the shell allows some action to the adductor, notwithstanding the symphynote hinge-line. *Mulleria*, which is dimyary and locomotive when young, becomes fixed and monomyary when adult, and it solders both the young valves to the beak of the fixed valve whilst the other is free and subject to the action of the adductor.

A condition similar to the *Pholades* occurs in the adult *Rhizochilus* (xliv, 33). Dr. Gray remarks of this singular genus that "the shell, while the animal is growing, is free; but when the animals have arrived at their full development, two or more congregate together in groups, each animal forming a more or less irregular, opaque, white, solid shelly extension of the outer and inner lip clasping the axis of the coral, *Antipathes ericoides*, or the neighboring shells, or both, and at length entirely closing the mouth of the shell, and firmly attaching the shells to the coral, or to one another, in such a manner that the animal is completely surrounded by a solid shelly case, having no communication with the outer world but through the case of the anterior siphon of the mantle, which, by the contraction of the mouth of the shell, has been converted into a shelly tube. This self-immurement of the animal within its shell has not been described in any other mollusk, and one is led to inquire if by so doing the animal commits voluntary suicide or has a prolonged existence; if the latter, one should expect that it must be of a very torpid or lingering description, as the animal is entirely precluded from procuring its usual or indeed any other food for its subsistence, and the supply of water for respiration which can enter by the single siphon must be of a very limited quantity, there being only one aperture for its entrance and exit. Many of the lung-breathing mollusca cover the mouth of their shell after the animal is withdrawn during very dry weather with a membranaceous or calcareous epiphragm, the animal during

the time sinking into a torpid condition ; but these animals have the power, at the first recurrence of damp weather, to remove this cover, which is not the case with the hard shelly secretions which cover up the mouth of the shell of *Rhizochilus*.”*

Notwithstanding the decided opinion given by Dr. Gray that the self-immurement of the *Rhizochilus* is permanent, I cannot help thinking that it only continues during a period of hibernation, and as many mollusks have the power of absorbing away partitions in their shells, as well as parts of the columella and the interior thickening of the outer lip, it appears to me that his argument that the hardness and thickness of the prison-walls would prevent escape, can scarcely be sustained.

In certain species of *Calyptræa* and in *Hipponix* the foot is atrophied. The mantle secretes not only the shell which covers the animal, but also, from its ventral face a calcareous base attached to some foreign body, and to this the mollusk adheres by a horseshoe-shaped muscle.

Magilus (xlv, 52) resembles the *Teredos* in constructing a tube, and for the same purpose. In *Magilus* the tubular growth is, however, a continuation of the growth of the shell margin, but changed in form, and in this respect it is more like the *Aspergillum*, which builds out a tube from the valves which lay open near the end and form part of its circumference.

A more or less irregular unrollment of the spiral takes place in *Vermetus* (lxvii, 68) and its allies, and to a less degree in certain Cuban *Cylindrellæ* and some other terrestrial mollusks. In the terrestrial genera *Hypselostoma*, *Tomigerus* and *Anostoma*, the adult character is proclaimed by a very curious change in the progression of the spiral by which the mouth of the shell is turned upwards to its superior or spire face: so in certain South American *Bulimi* the saccate body-whorl of the adult is deflected from the axis of the spire-whorls.

Sculptured shells, particularly *Ammonites*, and species of *Rostellaria* and *Fusus*, often become plain in the last part of their growth. But the most characteristic change is the thickening and contraction of the aperture in the univalves. The young cowry has a thin, sharp lip (lxi, 97), which becomes curled inwards, and enormously thickened and toothed in the adult; the *Pteroceras* (lix, 63) develops its scorpion-like claws only when full-grown; and the land snails form a thickened lip, or narrow their aperture with projecting processes, so that it is a marvel how they pass in and out, and how they can exclude their eggs.

Yet at this time they would seem to require more space and accommodation in their houses than before, and there are several

* Ann. Mag. Nat. Hist., 2d ser., vii, 477, 1851.

curious ways in which this is sometimes obtained. The Neritidæ, Helicinidæ and Auriculidæ (l, 14) dissolve all the internal spiral column of their shells; the cone (i, 8) removes all but a paper-like portion of its inner whorls; the cowry goes still further, and continues removing the internal layers of its shell-wall, and depositing new layers externally with its overlapping mantle (lxi, 99), until, in some cases, all resemblance to the young shell is lost in the adult.

The power which mollusks possess of dissolving portions of their own shells is also exhibited by the Murices in removing those spines from their whorls which interfere with their growth; and by the *Purpura* and others in wearing away the inner wall of their aperture.

Decollated Shells. It frequently happens that as spiral shells become adult they cease to occupy the upper part of their cavity; the space thus vacated is sometimes filled with solid shell, as in *Magilus*; or it is partitioned off, as in *Vermetus*, *Euomphalus*, *Turritella*, *Triton* or *Cæcum* (i, 11). The deserted apex is sometimes very thin, and becoming dead and brittle, it breaks away, leaving the shell truncated or decollated. This happens constantly with the *Truncatellæ*, *Cylindrellæ* (i, 12, 13), and *Bulimus decollatus*; amongst the fresh-water shells it depends upon local circumstances, but is very common with *Pirena* and *Cerithidea*.

Decollated shells usually have the whorls of the spire closely wound and not increasing much in diameter. Before the truncation takes place the partition or septum is formed which is intended to close the new summit. A number of tropical and subtropical terrestrial species, particularly of America, uniformly truncate their shells, the portion closed off from contact with the mollusk becoming dead and fragile so as to break away readily. M. Gassies has, however, observed *Rumina decollata* strike with the summit of its shell, with the evident purpose of fracturing it. In *Cæcum* also (i, 11), which commences growth as a spiral shell, a septum is formed soon after the close spire has been exchanged for a simply curved tube, and then the spire is detached. As the shell progresses in its growth another septum is formed and again it suffers truncation at its initial end, so that the adult *Cæcum* is a simple curved tube, differing from the *Scaphopoda* or *Dentalium* shells in the small end being closed instead of open, as in the "tooth shells." In the latter the posterior opening is for the extrusion of the eggs—which in these only, among encephalous mollusca, are accommodated with a separate aperture in the shell for their passage.

Forms of Shells. These will be described particularly hereafter; enough has been said to show that in the molluscan shell (as in the vertebrate skeleton) indications are afforded of many

of the leading affinities and structural peculiarities of the animal. It may sometimes be difficult to determine the genus of a shell, especially when its form is very simple; but this results more from the imperfection of our technicalities and systems than from any want of co-ordination in the animal and its shell.

Monstrosities. The whorls of spiral shells are sometimes separated by the interference of foreign substances, which adhere to them whilst young; the garden-snail has been found in this condition, and less complete instances are common amongst sea shells. Discoidal shells occasionally become spiral [as in *Planorbis* (i, 18)], or irregular in their growth, owing to an unhealthy condition. The discoidal Ammonites sometimes show a slight tendency to become spiral, and more rarely become unsymmetrical, and have the keel on one side instead of in the middle. Helices occasionally occur with tilted whorls, or even more or less unwound and scalariform (i, 16, 17).

All attached shells are liable to interference in their growth, and malformations consequent on their situation in cavities, or from coming in contact with rocks. The *Dreissena polymorpha* distorts the other fresh-water mussels by fastening their valves with its byssus; and balani sometimes produce strange protuberances on the back of the cowry, to which they have attached themselves when young. In the British Museum there is a *Helix terrestris* (Chemn.) with a small stick passing through it, and projecting from the apex and umbilicus. Mr. Pickering has, in his collection, a *Helix hortensis* which got entangled in a nut-shell when young, and growing too large to escape, had to endure the incubus to the end of its days. Fischer speaks of a *Helix aspersa*, which has entangled in its aperture a younger shell of the same species, which it has soldered fast, thus bearing two shells. Cailliaud has produced monsters by bringing dead shells in contact with growing ones.

In the miocene tertiaries of Asia Minor, Professor Forbes discovered whole races of *Neritina*, *Paludina*, and *Melanopsis*, with whorls ribbed or keeled, as if through the unhealthy influence of brackish water. The fossil periwinkles of the Norwich Crag are similarly distorted, probably by the access of fresh water; parallel cases occur at the present day in the Baltic.

Reversed Shells. Left-handed or reversed varieties of spiral shells have been met with in some of the very common species, like the whelk and garden-snail, and in some localities tend to become hereditary. *Bulimus citrinus* is as often sinistral as dextral; and a reversed variety of *Fusus antiquus* was more common than the normal form in the pliocene sea. Other shells are normally sinistral, as in many species of *Pupa*, and the entire genera *Clausilia*, *Physa*, and *Triforis*. Bivalves less distinctly exhibit variations of this kind; but the attached valve of *Chama*

has its umbo turned to the right or left indifferently; and of two specimens of *Lucina Childreni* in the British Museum, one has the right, the other the left valve flat.

Colors of Shells. These are usually confined to the surface beneath the epidermis, and are secreted by the border of the mantle, which often exhibits similar tints and patterns (e. g. *Voluta undulata*, liii, 14). Occasionally the inner strata of porcellaneous shells are differently colored from the exterior, and the makers of shell-cameos avail themselves of this difference to produce white or rose-colored figures on a dark ground. Cameos carved on the shell of *Cassis cornuta*, are white on an orange ground; on *C. tuberosa*, and *Madagascariensis* (lxii, 22), white upon dark claret-color; on *C. rufa*, pale salmon-color on orange; and on *Strombus gigas* (lix, 57), yellow on pink. By filing some of the olives (e. g. *Oliva utriculus*) they may be made into very different colored shells.

The secretion of color by the mantle depends greatly on the action of light; shallow-water shells are, as a class, warmer and brighter-colored than those from deep water; and bivalves which are habitually fixed or stationary (like *Spondylus* and *Pecten pleuronectes*) have the upper valve richly tinted, whilst the lower one is colorless. The backs of most spiral shells are darker than the under sides; but in *Ianthina* the base of the shell is habitually turned upwards, and is deeply dyed with violet. Some colors are more permanent than others; the red spots on the Naticas and Nerites are commonly preserved in tertiary and oolitic fossils, and even in one example (of *N. subcostata*, Schl.) from Devonian limestone. *Terebratula hastata*, and some Pectens of the Carboniferous period, retain their markings; the *Orthoceras anguliferus* of the Devonian beds has zigzag bands of color; and a *Terebratula* of the same age, from Arctic North America, is ornamented with several rows of dark red spots.

The Operculum. Most spiral shells have an operculum, or lid, with which to close the aperture when they withdraw for shelter (xliii, 7). It is developed on a particular lobe at the posterior part of the foot, and consists of horny layers, sometimes hardened with shelly matter.

It has been considered by Adanson, and more recently by Dr. Gray, as the equivalent of the dextral valve of the conchifera; but however similar in appearance, its anatomical relations are altogether different. In position it represents the byssus of the bivalves; and in function it is like the plug with which unattached specimens of *Byssarca* close their aperture.

Homologies of the Shell. The shell is so simple a structure that its modifications present few points for comparison; but even these are not wholly understood, or free from doubt. The bivalve shell may be compared to the outer tunic of the ascidian,

cut open and converted into separable valves. In the Conchifera this division of the mantle is vertical, and the valves are right and left. In the Brachiopoda the separation is horizontal, and the valves are dorsal and ventral. The monomyarian bivalves lie habitually on one side (like the Pleuronectidæ among fishes); and their shells, though really right and left, are termed "upper" and "lower" valves. The univalve shell is the equivalent of both valves of the bivalve. In the Pteropoda it consists of dorsal and ventral plates, comparable with the valves of Terebratula. In the Gastropoda it is equivalent to both valves of the Conchifera united above. The nautilus shell corresponds to that of the gastropod; but whilst its chambers are shadowed forth in many spiral shells, the siphuncle is something additional; and the entire shell of the cuttle-fish and argonaut have no known equivalent or parallel in the other molluscan classes. The student might imagine a resemblance in the shell of the Orthoceras to a back-bone. The phragmocone is the representative of the calcareous axis (or splanchno-skeleton) of a coral, such as Amplexus or Siphonophyllia.

Spines and Sculpture. It remains to speak of the sculpture and particularly of the spinous processes which adorn the shells of many univalves, as well as the valves of *Unio spinosus*, *Dione lupinaria*, etc. It is difficult in some cases to imagine the part which these play in the molluscan economy, unless it be to prevent greedy enemies from masticating them without exceeding discomfort. The formation of the spines depends upon folds of the mantle-margin, and regular as is the row of the long needle-like projections which ornament the lateral slope of Dione, they have nevertheless been formed one at a time on either valve at its margin: thus they indicate the periodicity of growth. In most cases marginal characters are absorbed away by the animal before commencing a new growth of its shell, but sometimes they persist both externally and internally—thus the varices of Murex are simply the thickened lips of former mouths, the recurring internal projections in the whorls of Segmentina, *Helix interna*, etc., are the marks of former rest-periods in their growth. Another class of external markings found only upon attached shells, such as Crepidula, Anomia, Myochama, etc., have no connection with the animal which forms them, but result merely from the plasticity of the newly formed shelly exudation, when brought into contact with the surface to which they are attached. Thus it is not unusual to find an Anomia covered with ribs crossing its surface at right-angles, or laterally to its axis of growth in consequence of having been in close contact with a Pecten.

A numerous class of deviations from the normal spiral is found in certain limpet-like mollusks as well as in Haliotis (lxxxiii). In these the spire has been reduced to a simple cone, or to a very

small size compared to the enormously large aperture, which hugs close to rocks, etc., to which the animal attaches itself by its much expanded sole almost as tightly as though it were a specialized sucker. The branchial cavity is placed in communication with the surrounding water in these genera by a special notch in *Haliotis* (lxxxiii, 10-13), which, by the progressive growth of the shell forms a series of dorsal apertures; the earlier ones finally becoming filled again with shell, but several always remaining open. In *Fissurella* (lxxxiii, 15), a similar but single aperture exists at the apex of the shell, and in several allied genera a similar provision is made only differing in form and position.

A large volume might readily be filled with interesting particulars concerning the shells of mollusca, but our space will only allow the above rapid resumé of the more important aspects of the subject. It remains to detail briefly the special relations of the shell to each class of mollusks, together with the nomenclature which has been adopted for the ready classification of its diverse forms.

Cephalopoda. An internal shell is found only in the dibranchiate cephalopods, and amongst them only fully developed in the decapod division, *i. e.*, among the pelagic species, whose quick movements require the support to the body which the form and position of the shell affords; nevertheless it is prefigured in the cartilaginous blades lodged in the back of the octopods (iv, 56), and is more fully developed in the single octopod genus, *Cirroteuthis* (iv, 58), which possesses the means of more rapid motion in its largely webbed arms.

The internal shell is simple usually, in form, being a blade or pen lodged in a pouch or slit in the back of the mantle, with an anterior, more or less specialized, prolongation of its rhachis or quill. The internal shell is either horny or chitinous and transparent as in *Loligo* (xxv, 21), or a spongy, chalky mass, as in *Sepia* (xxvii, 49), or calcareous, as in the fossil *Belemnites* (ii, 19, 21), or mother-of-pearl, as in *Spirula* (xxvii, 52); in the latter, only, taking the spiral form of the external shells of the tetrabranchiate cephalopods.

The feather-shaped horny shell of the *Loligo* resembles, and is called, a *pen*, and its rhachis, prolonged in front like a quill, completes the resemblance. This rhachis is on the ventral side, when the pen is lodged in the mantle, the wing end being posterior, the quill anterior. The wings, or lateral projections are, commonly, broader in the female than in the male individuals.

When the shell is both corneous and testaceous, as in *Sepia*, among recent genera and in several fossil forms, it consists of a thin, horny blade, laying beneath the entire dorsal surface of the

mantle, with an underlying spongy calcareous mass attached. In *Sepia* we find always, the so-called aerial chambers obliquely placed and not connected by a siphon, and sometimes terminated by a sharp rostrum, whilst in fossil genera, as *Beloptera*, these chambers are arranged in a single line, or in *Spirulirostra* (xxix, 81), they become a spiral series, connected by a siphon and analogous to the shell of the *Spirula* (xxvi, 53), which latter lies free in the mantle, without the envelopment of a spongy mass. In another group of fossil forms, the long shell is composed of a narrow or broad anterior corneous portion, and a posterior calcareous part containing the aerial chambers, placed one upon another and siphunculated. These chambers are only covered with shell in *Conoteuthis*; but they are protected in the *Belemnites* by a testaceous rostrum (ii, 19); sometimes very long, which, absolutely identical with that of *Sepia*, is composed of successive very compact radiating layers.

The internal shell, in relation to the animal economy, demands some further consideration. These functions, by reason of modifications of structure, are threefold:

1. If it is a corneous blade, it becomes simply a support to the flesh, fulfilling that office of the skeleton in mammals.

2. When it is corneous or testaceous, and containing parts filled with air, as in the alveola of the *Belemnites*, it, perhaps, additionally represents among mollusks the swimming-bladder of fishes. These air-chambers may consist, as we have seen, of an oblique series, separated in their interior by a crowd of small diaphragms, filled with air, and attached to the under side of the blade or cuttle-bone, as in *Sepia*; or even of a series of chambers taking a definite spiral form, as in *Spirula*. D'Orbigny shows that shells of this second division, when parted from their animals, are sufficiently light to float upon the surface of the waves, and that there is a constant coincidence of the progressive augmentation of the number of air-chambers with the growth of the animal, in order to maintain an equilibrium. The lightness of the shell of the *Sepia* appears to be partly due to a contained gas, which Dr. Paul Bert has succeeded in obtaining in small quantities, by opening the sack of the animal under water. In effect, the *Sepia* and the *Spirula*, animals of massive proportions, have need of this aid in swimming; and it is more plentifully supplied to the round-bodied *Spirula*, than to the *Conoteuthis*, for example, the form of which denotes an animal infinitely more agile. In the *Belemnites* the aerial chambers doubtless compensated the enormous weight of the calcareous rostrum, which would otherwise have compelled the animal to maintain a vertical position in the water, or prevented horizontal movement, except at great disadvantage to its strength. (In the chambered external shells of the tetrabranchiates, represented

amongst the extinct genera by the spirally-coiled Ammonites, and other genera, and largely developed in species, but of which the Nautilus is the sole recent example, the air-chambers may possibly compensate the weight of superincumbent water, and facilitate its crawling movements, if, as is now generally supposed, the Nautilus is not a swimming animal, and does not voluntarily leave its ocean-bed. The immense size and weight of the Nautilus shell, capable of containing the entire animal within its last chamber, the absence of long arms, or web or fins, all seem to favor this supposition as to its habits.)

3. Owing to their narrow posterior and massive anterior form, as well as to the normal direction of the siphon and the frequent use of the webbed arms in swimming, the cephalopods are able to progress through the water more rapidly in retrograde than in forward motion; and this swimming is a succession of darts made with great velocity. Here the calcareous rostrum, as in the Sepia, and which is so largely developed in Belemnites and other fossil genera, comes into use as a body-protector, in receiving and withstanding the shocks of accidental collisions. It is only among the swimming species that this protection is needed, and it is most required, and consequently most developed, in those which inhabit the vicinity of the coasts, like the Sepia.

Internal shells, having no aerial chambers, show no nucleus, and do not change their forms at different periods of their growth; but in most of those furnished with the air-chambers, a distinct nucleus is observed, indicated by the more globose first chamber, as in Spirula and Belemnites. Amongst these latter shells we find considerable modifications arising from age, sex or pathological causes. The changes resulting from age are, above all, visible in the rostra of the Belemnites, which, ordinarily slender when young, are thickened and shortened with advancing age. In exceptional cases, these rostra, when their growth is completed, present, at their extremity, very remarkable tubular prolongations. Modifications due to sex, are shown in the difference in width of the shell in Loligo, in the more or less elongated rostrum of Belemnites, perhaps, or in the prolongations of which we have just spoken. Pathological modifications are very numerous, above all in Belemnites. They may change entirely the form of the rostrum, by rendering it obtuse, or even cause those strange mutilations upon which the genus Actinocamax is founded.

The Spirula is peculiar in being formed exclusively of pearl (the Nautilus has an internal pearly layer); it hangs free in the hinder end of the body, held in place solely by lateral thin lappets of skin proceeding from either side of the mantle, and connate below the whorls, with a prehensile prominence or

sucker at their junction. A small portion of the intestinal sack occupies the last chamber of the shell, and a prolongation of it connects the chambers by passing through the siphonal tubes which penetrate the septa towards their inner margin (instead of in the middle, as in *Nautilus*).

In the fossil Belemnites, the siphunculated, chambered portion of the shell has been called the phragmoconus, by Owen; the horny or chalky blade is termed, by Huxley, the pro-ostracum, and the rostrum of the latter author corresponds with the similar term heretofore used by us (ii, 19-21).

Analysis shows the horny shell to be principally composed of chitin. The *Sepia officinalis*, according to J. F. John, yields of Carbonate of Lime, with a trace of Phosphate, 85°; Water, 4°; Organic matter, 4°; Residuum, Magnesia, etc., 7°.

M. Munier-Chalmas has recently endeavored to prove that the Ammonites are not tetrabranchiate Cephalopoda, allied to the Nautili, but dibranchiate decapods, having the greatest affinity to the Spirulæ. As early as 1867, Barrande had shown the small resemblance that exists between the Goniatites and the Nautilidæ, during the first period of their development. The initial chamber of the *phragmostracum* in the Nautilidæ, does not sensibly differ, in its general organization, from the other primary chambers which are developed a little later; whereas the initial shell of the Goniatites appears in the form of an egg, isolated from the first air-chamber by a distinct constriction. This initial chamber or *ovisac*, of the Goniatites, so different from those which immediately succeed it, is met with at the origin of the phragmostracum of all the dibranchiate mollusca that M. Munier-Chalmas has been able to study. Mr. Alpheus Hyatt's very interesting investigations upon the embryogeny of the phragmostracum of *Nautilus Pompilius*, *Deroceras planicosta*, and the Goniatites, come in support of these observations. Mr. Hyatt, however, preoccupied by his theoretical ideas upon the evolution of living creatures, in order to establish the affiliation of the Ammonites and Nautili, supposes that the latter lost their ovisac by truncation. To support this supposition, he adduces the transverse external cicatrix which he observed on the initial chamber of *Nautilus Pompilius*. The comparative examination which M. Munier-Chalmas has made of the ovisacs of *Spirula Peronii* and of *Ammonites Parkinsoni*, and other species, has shown that in these mollusks the siphon originates in the ovisac a little before the appearance of the first septum. It commences by a cæcal inflation, which bears the prosiphon in its prolongation. The new organ, to which he gives the name of prosiphon, must take the place of the siphon during the embryonic period. It originates in the ovisac, opposite the siphonal inflation, upon which it terminates, but without having any internal communi-

cation therewith. It is very variable in its general form, and may present strongly marked examples of dimorphism in the same species of Ammonite. It is formed by a membrane, which is sometimes simply spread out as in *Spirula Peronii*, or which may form a more or less circular tube. It also presents two, three, or four small subdivisions at its point of insertion upon the inner wall.

The presence of an ovisac has been ascertained by M. Chalmas in a number of fossil cephalopods, Belemnites, Ammonites, Ceratites, etc. It is generally spheroidal when the turns of the spire are free, and ovoid when they are contiguous. But in the living tetrabranchiate Cephalopoda, as well as in the remains of the many extinct species, the presence of an ovisac has never been detected. In Nautilus and Aturia, the siphon originates upon the inner walls of the first chamber. It is completely closed at its posterior extremity, by a part of the calcareous prolongation of the septum, which assists in its formation. The external transverse cicatrix observed by Mr. Hyatt, can never have been in communication with the siphon; its purpose is still completely unknown. It has been indicated, by Mr. Barrande, upon a great number of Silurian tetrabranchiata.

Thus it results, from these observations, that at the Silurian epoch the tetrabranchiate Cephalopoda were as clearly separated from the dibranchiates, as at the present day. The only modifications that we can recognize are of generic rank; in fact, the Ammonites, which, when young, have septa like those of Dero-ceras and Goniatites, appear to be derived from one of those types.—*Ann. Mag. N. Hist.*, 4th ser., xiii, 184, 1874 (from *Comptes Rendus*, 1873).

External Shell in the Cephalopoda. Regarding the testaceous nest of the female Argonaut as a shell, it is the only cephalopod genus which is unilocular; in all others the cavity of the external shells is divided by partitions into chambers, connected by a siphon. The Argonaut shell (xxiv, 19), of a peculiar fibrous, corneo-calcareous texture, is distinguished by the want of a distinct nucleus in its infancy, and by its composition of two layers, one placed upon the other. It is secreted by the palmate arms of the female, which are constantly applied to its sides and envelop them (xxiv, 20). In the male Argonaut, always much smaller, there are no palmated arms (xvi, 84, 85), and consequently, no shell. The shell itself appears to be useful only as a portable cradle for the development of the eggs (xviii, 15), and the animal which forms it does not appear to differ greatly from the shell-less Octopus.

The question of the parasitism of the animal of the Argonaut in its shell, originally assumed by distinguished naturalists, has been so long debated, that quite a literature upon the subject has

accumulated. The want of attachment of the animal by adductor muscles, and the fact that the shell itself is not moulded on the animal's body, and does not correspond to its shape were considered such strong evidence of parasitism, that the animal itself was described as *Ocythoë*, and the shell as *Argonauta*. The observations of Madame Jeanette Power first set this vexed question at rest, by showing that the animal builds its shell by the exudation of material from the expanded or velamentous arms of the female, instead of from the mantle, as in true shells.

The Argonaut shell, or egg-nest, is structurally composed of small plates or prisms; its earlier portion is covered with a chagrined cuticle, and its toothed periphery is stained with brown. On either side the velamentous dorsal arms are applied to its external surface, and not only do they add to the margin when growth takes place, but they suffice also to renew any broken portion of the already existing walls.

In a specimen of *Argonauta argo*, which forms a part of the collection of Amherst College, a portion has been broken out near the middle of the left side, and not far from the sinus of the aperture. A new deposit of testaceous substance, together with a broken fragment, has closed the opening in the rude manner common in the shells of the mollusca. But the most extraordinary circumstance is that a fragment which was broken out in the accident which befell the animal, now constitutes two-thirds of the repaired portion, and that the original inner surface is now the outer surface, as is evident from its concavity, style of undulation, and texture. It is also nearly at right-angles to its original position. These facts show that the piece was totally detached from the shell by the accident. The vela of the Argonaut, by clasping and enveloping the shell, had evidently prevented the loss of this fragment. It is obvious, also, that the new deposit of testaceous matter was secreted from the part of the animal within the shell, and not from the vela, since the edges of the original shell around the fracture appear exclusively on the outside.—C. B. ADAMS, *Am. Jour. Sci.*, 2 ser., vi, 138, 1848.

Madame Power has seen the fractured shell of an Argonaut partially repaired by membrane in less than six hours.

The subjoined notes of an accurate modern naturalist afford conclusive evidence of the non-parasitism of the Argonaut.

On our passage home across the South Atlantic, I enjoyed numerous opportunities of observing the animals of *Argonauta argo* and *gondola* in the living state, specimens having been captured by us in large numbers by means of a trawl, as they came to the surface of the water at the decline of day in calm weather, in company with *Carinaria*, *Hyalæa*, *Firola* and *Cleo-*

dora. My observations all tend to prove, as might have been expected, the accuracy of Madame Power's observations on the cephalopodic origin of the shell, and the fanciful nature of the statements of Pliny, Poli, and the poets.

It is quite true that the female Argonaut can readily disengage herself from the shell, when the velamentous arms become collapsed, and float apparently useless on each side of the animal; and it is equally certain that she has not the power, or, more properly, the sagacity to re-enter her nest and resume the guardianship of her eggs. On the contrary, she herself, if kept in confinement, after darting and wounding herself against the sides of the vessel in which she is confined, soon becomes languid, exhausted, and very shortly dies. Numbers of male Argonauts were taken by us, at the same time, without any shells, and this being the season of ovoposition may account for the females, in such a number of instances, being found embracing their calcareous shell-nests, which, so ingeniously formed by the instinct of the mother for the protection of her eggs from injury, resemble, in some measure, those nidimental capsules secreted by many marine gastropods for the preservation of the immature embryo.—ARTHUR ADAMS, Zool. Voy. Samarang, 5, 1850.

The *multilocular* external shells, Nautilus, Ammonites, etc. (iv, 63), distinguish an order of cephalopods breathing by four instead of two branchiæ, and with the arms much reduced in size and subdivided into tentacles. The shells are capable of containing the entire animal in the cavity above the last aerial chamber, to the wall of which it adheres by two strong muscles. These shells are composed of two layers, the external or porcellaneous containing the colors, and the internal, which is pearly, and which includes the partitions or *septa*. These *septa*, which are straight or arcuated in Nautilus, in Orthoceratites, etc., are angulated at the *suture* in Goniatites, and with infinitely ramified lobes in Ammonites (xxxiv, 52), Hamites, Turrilites, and other fossil genera.

The inner pearly layer of the shell, as well as of the *septa*, is formed by the body of the animal, whilst the outer porcellaneous layer is constructed by the mantle-margin. There is additionally deposited, on the spire side of the Nautilus shell, a third thin, black, grainy layer, which can be readily scraped off. This substance can be detected also in many fossil tetrabranchiates.

Sandberger finds the hardness of the porcellaneous layer of Nautilus, 4.5 to 5.0; the nacreous layer, 3.5 to 4.0; whilst the specific gravity of the former is 2.565, and of the latter, 1.596.

The structure of the shells of existing testaceous cephalopods is, on the whole, more analogous to that of bivalves than to that of the gastropods, the three layers of perpendicular laminae, so

characteristic of the latter, being here quite indistinguishable. The shell of *Nautilus* is the only one in which the presence of two layers is obvious, from their difference of texture. A thin section of the external layer of the shell of *Nautilus Pompilius*, taken parallel to the surface, shows that it is made up of an aggregation of cells of various sizes, those strata which are nearest the surface being the largest. The internal or nacreous layer is also distinctly cellular.

The body of the animal of *Nautilus*, which is applied to and forms the septum, is of similar smooth and rounded form, and we may reason from analogy that the arborescent lobes of the septum in the fossil Ammonites, were likewise moulded upon a similarly formed surface. If we seek a use for this complication of structure in Ammonites, we shall find a possible explanation in the connecting siphon which, piercing the centres of the septa in *Nautilus*, enables the animal thereby to strengthen its hold upon its shell, but piercing laterally in Ammonites, gives only an excentric attachment. In the latter case, the lobes and ramifications, applied to the corresponding parts of the animal, would tighten its attachment, and partially remedy the want of the central support.

The outlines of the septa are termed *sutures*, and when these are folded, as in Ammonites, etc., the elevations are called *saddles*, and the depressions, *lobes* (xxxv, 72; ii, 28, 29). This frilling or folding is found principally at the junction of the septum with the shell-wall, the former being nearly flat in the middle, even when its sutural complication is extreme. These parts are subdivided thus: A single *siphonal* or *ventral lobe* surrounds the siphon, and occupies the medial region of the back, and the additional two lobes on either side of it are named the *superior lateral lobes* and *inferior lateral lobes*, whilst other lobes, whatever their number, are called auxiliary lobes; finally, opposed to the *siphonal* is the *antisiphonal lobe*. The saddles bear a corresponding nomenclature, that between the ventral lobe and the superior lateral, being termed the *ventral saddle*, the next the *lateral saddle*, etc.

All multilocular cephalopods have the chambers of their shells connected by a siphon, which traverses the septa, and receives from the latter a series of short investing tubes.

The siphon pierces the middle of the septa in *Nautilus* (ii. 23), in *Orthoceratites*, etc., whilst it is near the internal edge in *Clymenia* (ii, 24), and the outer edge in *Goniatites*, Ammonites, etc. (ii, 25).

It has been supposed by Buckland, that the siphon, which communicates with a large sack, discovered by Owen, in the body of *Nautilus Pompilius*, may constitute a hydraulic apparatus by which the animal may vary the weight of its shell at will by

introducing water into it; but the narrow calcareous covering which partially confines this tube, preventing dilatation, militates strongly against this hypothesis. D'Orbigny's guess seems more reasonable, that this tube may not only serve as an attachment, but that it may also assist in the formation of a new septum, by keeping filled with compressed air the vacant space, in the rear of the animal, which is to be divided off. Prof. Keferstein, of Göttingen, supposes, also, that the *Nautilus Pompilius*, in order to raise itself in its shell to the place where it designs constructing a new partition, employs the tension of an aeriform fluid, which it produces from the bottom of its sack, and which presses its body upward. The air disengaged by the *Nautilus* develops a considerable force, because it conquers not only the resistance of weight of the animal itself, but also that of the weight of about six atmospheres, which presses upon it in its habitual station at the bottom of the sea. Prof. Keferstein decidedly agrees with Woodward and others, that the adductor muscle of *Nautilus* continuously grows forward, and is reabsorbed behind, rather than suddenly moved as supposed by d'Orbigny. Then if these attachments added to that of the continuous horny girdle suffice to hold the animal to its position, the septum, as Woodward shows, would result from a rest-period, and should at least be externally distinguishable among the growth-lines of the exterior surface.

It is only the backs of the septa which are covered with membrane, and this membrane may be required to maintain the vitality of the shell in the deserted chambers. Keferstein also considers it most likely that the siphon serves to maintain the purity of the air in the chambers. The *Nautilus* may swim, being provided with a locomotive tube or siphon, but it certainly is not well adapted by its structure for that mode of progression, and probably prefers the sea-bed.* Still, the specific gravity of shell and animal so nearly equals that of the sea-water that probably the additional displacement caused by spreading out to the utmost its tentacles would cause it to rise in the water. It is just possible that when the *Nautilus* issues from its shell the gas contained in the last chamber in the rear of the animal may expand, and so reduce the specific gravity.

The siphuncle is vascular, it opens into the heart-cavity (pericardium), and is most probably filled with fluid from it.

* Mr. A. S. Bickmore, who collected Nautili at Amboina, observes that it has been commonly believed that the *Nautilus* occasionally rises to the surface, and "setting its sails, floats over the sea." This was first reported by Rumphius, but, after making continued and careful inquiries, he had satisfied himself that there is no reason to suppose that the animal ever rises from the bed of the sea.—*Proc. Bost. Soc. N. H.*, xii, 157, 1868.

Woodward says (Man. Moll., p. 184): "The use of the air-chambers is to render the whole animal (and shell) of nearly the same specific gravity with the water. Thus a *Nautilus Pompilius* in the cabinet of Mr. Morris weighs 1 lb., and when the siphuncle is secured it floats with a half-pound weight in its aperture. The animal would have displaced two pints or 2.5 lbs. of water, and, therefore, if it weighed 3 lbs., the specific gravity of the animal and shell would scarcely exceed that of salt water. The object of the numerous partitions is not so much to sustain the pressure of the water, as to guard against the collisions to which the shell is exposed. They are most complicated in the Ammonites, whose general form possesses least strength. The complicated sutures perhaps indicate lobed ovaries; they occur in genera which must have produced very small eggs. The purpose of the siphuncle (as suggested by Mr. Searles Wood) is to maintain the vitality of the shell during the long life which these animals certainly enjoyed. Mr. Forbes has suggested that the inner course of Hamites broke off as the outer ones were formed. But this was not the case with the Orthocerata, whose long, straight shells were particularly exposed to danger; in these the preservation of the shell was provided for by the increased size and strength of the siphuncle, and its increased vascularity."

The specific gravity of the chambered shells of cephalopods being such as to enable them to float upon the surface of the water, explains the cause of large quantities of shells of *Spirula* being washed ashore in localities removed many hundreds of miles from the habitat of the animal; it also explains satisfactorily two interesting palæontological facts, namely, the innumerable quantity of fossil shells found in beds which represent ancient beaches, and their absence from those beds which formed sea-bottoms.

External cephalopodous shells are all symmetrical except the genera *Turrilites* (xxxiii, 37), and *Helicoceras*; these latter instead of forming a spiral rolled in the same plane, are obliquely spiral; that is, on one side is the projecting spire of the shell, on the other the umbilical opening or axis of the volutions. The symmetrical forms, very numerous, vary all the way from a straight to a coiled growth, their difference in plan of growth constituting the generic distinctions. In some genera a change of form takes place after they have attained a certain age. In *Lituities* the shell commences with an open spiral (with disjointed whorls), and finally grows in a straight line. In *Ancylloceras* (xxxii, 33), the commencement is similar, but after elongating the whorl for awhile the extremity is incurved. And in *Scaphites* (xxxii, 35), a similar mode of growth to *Ancylloceras* is distinguished nevertheless by the initial spiral whorls being in contact. All other modifications caused by age, do not change

the form but merely the external surface of the shells. Some fossil Nautili, for instance, striated when young, become smooth at a later period, whilst others smooth when young are striated or ribbed when adult. So in the Ammonites, the juvenile shell is always smooth, but in the course of growth, tubercles, ribs and striæ appear, and develop until the animal has become adult; after this period degeneration takes place, the ornaments gradually disappear in the successive growths, and in old age the surface of the outer whorl may be as smooth as in youth. In Ammonites of the same species two forms of shells may be observed, one much compressed, the other swollen; and it is reasonable to conjecture from analogy with living species that the sexes are thus indicated to us, the swollen shell being required for the ovary of the female.

It will be seen from the above that the study of the species of multilocular shells is encompassed with great difficulties, owing to the variability of their characters; in fact the synonymy of the species of Ammonites has been greatly increased in consequence of several names being given to the same species at different periods of its growth.

The living Nautilus also, undergoes a change of form. At a recent meeting of the Boston Society of Natural History, Prof. Bickmore exhibited fifteen shells of *Nautilus Pompilius* of various sizes, from one which measured five-sixths of an inch by one inch and one-sixth in its two diameters, to one measuring two and five-sixths inches by three and three-fourths inches in its two diameters. The smaller ones are so loosely coiled that it is possible to look between the coils. These young specimens therefore represent the loosely coiled Nautiloids of former geological ages; and the *Nautilus Pompilius* at the different stages of its growth is an epitome of the whole group.

The *body-chamber* is always very capacious; more than double the size of the combined air-chambers in *Nautilus Pompilius* (iv, 63), it includes in some Ammonites (ii, 27, 28), more than an entire whorl of the shell. The margin of the aperture, somewhat sigmoid and simple in Nautilus, has projections or extensions in some fossil species; and in Phragmoceras and Gomphoceras (xxx, 100-1), the aperture is even so considerably contracted as to have led to the supposition that the animal was not able to withdraw its head and tentacles within the shell.

In these curious silurian forms M. Barrande thinks that the neck was inclosed in the upper part of the aperture, the lateral lobes giving passage to arms, and the lower lobe to the funnel. But there is some reason to believe that many of the fossil Ammonites possessed a more effective method of closing their aperture; namely, a horny or shelly operculum. In the Nautilus the union and expansion of the two dorsal arms forms a disk or

so-called *hood* (iv, 62), by which the animal may close the aperture of the shell, and in the body-chamber of many of the Ammonites (possibly secreted by these dorsal arms) there are opercular-shaped bodies (ii, 33). The true nature of these shelly or flexible horny plates has not been authoritatively settled however; they have been described under the names of Aptychus and Münsteria as bivalve shells, and have, also, been thought to be cirripeds and even products of the neck-cartilages, of the nidimental gland, gizzards, or ventrally placed cuttle-bones! of Ammonites. In the Arietes group of Ammonites the aptychus is a single, horny, flexible piece, whilst in other groups it is shelly, consisting of two plates joined by a median suture, the exterior face smooth or striated and the interior marked by growth-lines. Prof. Waagen has recently adopted the theory first advanced by Keferstein, and afterwards supported by Zittel, that the aptychi were connected with the nidimental gland, and he has even proposed a classification of Ammonitidæ based upon the absence or presence, and peculiarities when present of these bodies.

If, as Férussac first suspected, the Ammonite was a dibranchiate cephalopod, with the shell like that of the *Spirula* more or less completely covered by the posterior portion of its body, instead of being a tetrabranchiate with external shell like the *Nautilus*, then the difficulty of accounting for the presence of the aptychus is increased, if that body is truly a product of the nidimental gland; moreover, the outer layer of the shell estimated as epidermal in character, must be otherwise explained. It is difficult to imagine a shell internal, that is provided with the spinous processes of some of the species, and hard to reconcile the weight and size of sundry "cart-wheel" Ammonites with the idea of an internal shell. Fischer, however, appears disposed to take this view of the subject, following Hyatt and other recent investigators. For myself, I prefer leaving Ammonites among the tetrabranchiates, and, consequently, considering its shell as external, and that the aptychus is essentially an operculum, or a product of the "hood" which exists in *Nautilus*, and may have similarly existed in Ammonites.

Von Jhering finds in the aptychus a possible product of the cartilaginous neck-button of dibranchiate decapod Cephalopoda—that is, supposes them to be a product of a similar organ; and upon this theory he would consider them dibranchiates instead of tetrabranchiates. The use of the neck-button is not so apparent in an animal having a heavy external shell for its protection, and if the shell be considered internal, as in *Spirula*, and the animal also similar, it would be difficult to imagine how the aptychi occur in the body-chamber.

The outer layer of the shell has been generally destroyed in

fossil Ammonites, etc., leaving only the inner or nacreous and more indestructible layer, which thus exhibits perfectly the edges of the septa; but in some cases it is only the outer layer that has been preserved; and frequently when the whole shell has disappeared, we have perfect *casts* of the chambers. The decomposition of the animal has contributed to form those phosphates and sulphides generally present in the body-chamber, whilst the permeation of water deposits crystals of calcareous spar on the inner walls or sometimes even fills the entire chamber. Cross-sections of fossil Ammonites with the chambers filled with spar, when polished, make beautiful cabinet specimens. Sometimes, as in some of the Orthocerata, the circumjacent mud has invaded the air-chambers, but without entirely filling them, because the contraction of the vascular lining has left empty spaces between itself and a portion of the wall of each chamber.

Gastropoda are mostly provided with an external shell, a dwelling-place and a citadel combined, the hardness and durability of which, as Keferstein remarks, "supplies us with the best means of knowing the animal: indeed, in many cases, it is the only part known, and was formally the only part valued and preserved in collections. Although the animal itself offers more weighty and striking characters for the separation of the higher groups, yet having learned the close relationship existing between shell and animal, we find therein ample justification for attaching especial importance to the shell in a systematic point of view."

We have already shown how the shell is produced by the mantle.

The form of the shell is throughout regular, and is normally a cone curved into a spiral, and descending in a screw-like manner from the apex or initial whorl to the aperture (ii, 30). Nothing can be more beautiful than the regular geometrical progression of the growth of a shell or the certainty with which each species and genus grows in its normal pattern, although these modes vary among themselves so widely; thus we have the simple depressed cone of the *Patella* (lxxxiii, 25), all aperture and no spire, and from it every gradation, from the *Haliotis* (lxxxiii, 9), almost equally depressed and broad, the result, however, of a very rapidly enlarging spiral, to the long, many-whorled *Turritella* (lxvii, 59), or the *Vermetus* (lxvii, 68), which is a *Turritella* partially unrolled into a simple long tube;—the opposite of the *Patella*. The whorls of a spiral shell are, in most cases, closely wound around its axis, and, therefore, most part of their surface is in contact, each whorl partially covered and concealed by its successor; and where the axis does not lengthen by the obliquity of the spiral, we find, as in the cone (lviii, 42),

and *Cypræa* (lxi), that the shell only shows externally its last whorl, with, perhaps, a very small portion of its predecessors visible on the spire. On the other hand there are genera in which the whorls are not at all in contact, and where the axis becomes itself an imaginary cone, widest at the base. Besides the almost numberless modifications of form resulting from the degree of obliquity and closeness of the spiral, the direction of the latter may be mentioned as another factor in producing modification. In most spiral shells the spire normally curves to the right, that is to say, placing the shell with its apex turned from the observer and its aperture in view, the latter will be found on the right hand. In others the volutions proceed in the opposite direction with such regularity as to be eminently characteristic of some species and genera (*Physa*, *Clausilia*, etc.). However, in certain genera, it is found that species normally dextral will exceptionally produce sinistrally coiled shells, and *vice versa*, and this abnormal growth probably is caused by disturbance of the relations of the embryo with its initial shell.

Whilst the bulk and weight of these shells are composed principally of carbonate of lime, yet they have always an organic basis, which is first developed, and then gradually impregnated with the lime. If the latter be removed by the use of acids the organic residuum (conchyolin) still retains the shape of the shell, forming a sort of membranous framework. It is this organic basis which maintains the life of the shell, for, the animal removed as in beach-worn or fossil species, the conchyolin soon disappears and the shell becomes pure carbonate of lime, growing at the same time more and more brittle.

There are, as before stated, three layers of deposition (of which the middle one is thickest in many cases), each composed of a multitude of plates or prisms, but each differing in the direction of arrangement of these. It will be readily perceived how much this diversity of arrangement adds to the toughness of the shell structure, as no line of fracture can penetrate the entire shell wall, except by the violent breaking across of part of these layers of prisms.

As to the chemical composition of shells, the conchyolin or organic material is a small, varying percentage, carbonate of lime, existing in quantities varying, from *Turritella*, 88·70 per cent. to *Strombus gigas*, 99 per cent. There are traces of other constituents, of which carbonate of magnesia is perhaps one of the most important; it varies from 0·12 per cent. in *Telescopium* to 0·48 per cent. in *Fusus antiquus*. Silicic acid has also been detected. C. Schmidt has obtained almost 1 per cent. of phosphate of lime from the shell of *Helix memoralis*. The calcareous operculum of *Turbo* (analyzed by Wicke) contains: Carbonate of lime, 98·72 per cent.; organic material, 1·28 per cent. The

American oyster, according to Prof. Wm. B. Rogers, contains: Carbonate of lime, 95.18 per cent.; phosphate of lime, 1.88 per cent.; siliceous, .40 per cent.; water, 1.62 per cent.; animal matter, .45 per cent.

Shells are perceptibly harder than, and will scratch calc-spar. Their specific gravity is somewhat higher than that of Carrara marble, being about 2.75 to 2.85 for the prosobranchiates, and varying but slightly in the pulmonates.

With reference to the coloring of shells (terrestrial as well as marine species) Fischer points out that as a rule, brilliancy of coloring increases towards the equator. He suggests three zones of coloration corresponding to the thermal zones, which may be designated as:

1. Monochromic or frigid zone.
2. Oligochromic or temperate zone.
3. Polychromic or tropical zone.

Of course exceptions are numerous—modifications based upon habits, ocean currents, adaptive coloration, etc. M. Fischer particularly cites the melanism which characterizes so many shells of the West Coast of North and South America, giving, among other examples, the numerous species of sad-colored and lugubriously-named *Trochi*, which pervade those regions.*

On Protective Coloration. A number of papers on mimicry or adaptive resemblance as a means of protection of mollusks against their enemies have been published, and the subject has awakened much interest and discussion. Coincidence of coloration of molluscos animals with their surroundings has been frequently remarked, but it is probably not so often for purposes of attack or security as the result of the food upon which they live or a dye obtained by contact with it. Mr. Morse gives a number of instances of coincidence of color between American marine mollusks and their surroundings which he supposes to be evidences of protective adaptation† of these, three principal species of *Crepidula* or slipper-limpet, may be cited: *C. fornicata* is drab, variously rayed and mottled with brown, and it lives attached to stones or on the outside of shells of similar color; *C. convexa* has a dark brown shell, and is found on *Ilyanassa obsoleta* or on the roots of sea-weed; *C. plana* is white, and inhabits the *inside* of the aperture of dead shells, which is also white. Mr. Melvill mentions that *Ovulum uniplicatum*, as it is found on the Florida coast, is yellow or purple according to the color of the gorgonia on which it occurs.

"The thickness, the roughness, and the smoothness of the surface of shells appear to depend, in a great measure, on the

* Dr. P. Fischer, *Jour. de Conch.*, xxiii, 105, 1875.

† E. S. Morse, *Proc. Bost. Soc. Nat. Hist.*, xiv, 141, 1871.

stillness or agitated state of the water in which they reside. Shells which have branching or expanded varices, like the Murices, are also much influenced by circumstances, and hence many mere varieties, arising from local causes, have been considered as distinct species. Thus *Murex anguliferus* is merely a *Murex ramosus* with simple varices; and *Murex erinaceus*, *M. torosus*, *M. subcarinatus*, *M. cinguliferus*, *M. Tarentinus*, and *M. polygonus* are all varieties of one species. *Murex Magellanicus*, when found in smooth water, is covered with large acute foliaceous expansions; but the same shell living in rough seas is without any such expansions, and only cancellately ribbed. In such situations it seldom grows to a large size; but when it does so, it becomes very solid, and loses almost all appearance of cancellation. *Triton maculosus* is very widely spread over the ocean in different temperatures and different kinds of seas; it consequently offers a multitude of varieties both of size and surface, all gradually passing into each other, and most probably produced by the operation of the foregoing causes. Indeed, a vast number of merely nominal species have been formed from the habit, too prevalent among conchologists, of describing from single specimens, or even from several individuals brought from the same locality, which would never have been considered as distinct had collectors kept in their cabinets a series of specimens found under different circumstances, and studied on the coasts where they are found, the variations which shells undergo."—Dr. J. E. GRAY, *Philos. Trans.*, 771, 1833.

I have inserted the above as a sort of warning to species-makers and because my own experience partially confirms it; but Dr. Gray was too apt to propose theories in explanation of difficulties and to find illustrations and confirmations of such theories in hasty assumptions rather than by the careful observation of facts.

Rest-periods in the growth of mollusks are sometimes, as in the Murices, marked by a thickening of the edge of the shell, caused by continuous depositions of shell-material, forming a ridge or varix; and the rate of growth may be thus traced readily, in numerous mollusks. Thus in *Murex* one group shows three varices upon each whorl (xliii, 5), indicating that a period of three years, or at least three seasons of activity is required for the completion of a single whorl of growth. In another group of Murices the varices are more numerous (xliii, 7), as many as four to ten being counted on a whorl. In *Triton*, the varices are two on each whorl, but nearly alternately situated (xlvi, 54) so that the varices of each whorl occupy an intermediate position to those on the preceding whorl; in *Ranella* there are also two varices but they form a continuous fringe or wing-

like expansion on each side of the spire (xlvi, 69), showing a very regular growth by periods of half-whorls.

The accretion of surface during growth is not continuous but is made by minute layers, around the margin of the aperture, each extending a little beyond its predecessor, and the edges of these layers as exposed on the external surface are called growth-lines. Those shells which have a simple, or sharp-lipped aperture and which do not develop varices, nevertheless distinctly show the rest-periods by the greater impression of the growth-lines. Many shells retain the sharp aperture for a variable period, which may be called their juvenescence, but finally acquire adult characters, consisting of a thickened, reflected, inflected or lipped aperture—which is sometimes more or less contracted by inflected calcareous projections called teeth. Growth, however, frequently continues after adult characters have been acquired, and then these are usually absorbed away when accretion recommences, leaving the mark of their former position in a more prominent growth-scar or line.

The power of dissolving their shells is possessed by certainly a large portion of the mollusca; thus the cone, which we have seen partitioning off its whorls against an enemy and thus seriously incommoding itself for room, would under normal circumstances acquire for itself additional accommodation by absorbing away most of the thickness of the enclosed whorls or partitions, and *Cypræa*, *Nerita* and *Auricula* (i, 14), assist themselves in the same manner so as to become eventually an external shell only, with a single cavity. In species with lengthened spire, this method is not so practicable, because only a small portion of the whorls are enclosed within succeeding ones.

From what has been said of the mode of formation of shells it will be readily seen that details of sculpture as striae, sulcations, ribs, nodes, spines, etc., result from similar ornamentation of the applied mantle; thus the spine of a *Murex*, if closely examined, will be found to have a longitudinal seam upon its front face, showing that it has been formed by a corresponding digitation of the mantle. It is scarcely necessary to pursue this subject further at this time; reference to the plates will demonstrate this relationship of shell and animal.

The following are the principal modifications of form in the gastropod shell.

A. Regularly spiral.

- a. Elongated, subulate, elevated. *Terebra* (lvii, 11).
- b. Turritid, turriculated, babylonian; an elongated shell with the whorls angulated or shouldered on their upper part. *Turritella* (lxvii, 56).
- c. Cylindrical, pupiform. *Cylindrella*, *Pupa* (i, 12).

- d.* Short, bucciniform. *Buccinum* (1, 27).
- e.* Fusiform, spindle-shaped. *Fusus* (xlvii, 70).
- f.* Contabulate, short, with shouldered whorls (xlvii, 82).
- g.* Globular. *Natica* (lxiii, 44).
- h.* Gibbous. Whorls swelled beyond the normal contour of increase (usually on the aperture side). *Streptaxis*.
- i.* Depressed, lenticular. *Rotella* (lxxix, 95).
- j.* Discoidal. *Daronia* (lxxix, 90).
- k.* Convolute; aperture as long as the shell, nearly or quite concealing the spire. *Cypræa* (lxi, 96).
- l.* Trochiform, pyramidal, conical with a flat base. *Trochus* (lxxx, 39).
- m.* Turbinate; conical, with rounded base. *Turbo* (lxxx, 29).
- n.* Cone-shaped, obconic. *Conus* (lviii, 42).
- o.* Few-whorled. *Helix haemastoma*.
- p.* Many-whorled. *Helix polygyrata*.
- q.* Ear-shaped. *Haliotis* (lxiii, 10).
- B.* Scalariform, whorls not impinging. *Scalaria* (lxvi, 42).
- C.* Irregularly spiral, evolute. *Siliquaria* (lxvii, 79). *Vermetus* (lxvii, 68).
- D.* Tubular. *Dentalium*, or tooth-shell.
- E.* Shield-shaped. *Umbrella* (lxxxix, 89).
- F.* Boat-shaped, slipper-shaped. *Navicella* (lxxviii, 76). *Crepidula*, (lxv, 92).
- G.* Conical or limpet-shaped. *Patella* (lxxxiii, 26).
- H.* Multivalve and imbricated. *Chiton* (lxxxvi, 85).

The only *symmetrical* shells are those of *Carinaria*, *Atlanta*, *Dentalium* and the limpets.

The cavity of the shell is a single conical or spiral chamber; no gastropod has a multilocular shell like the *Nautilus*, but particular species, as we have seen, form spurious chambers by partitioning off the whorls; many form such partitions as a protection against the attacks of boring animals, or when the upper part of the spire is destroyed. Some spiral shells are complete tubes with the whorls separate or merely in contact, as *Scalaria*; but more commonly the inner side of the spiral is formed more or less by the previous whorls.

The axis of the shell, around which the whorls are coiled, is sometimes open or hollow; in which case the shell is said to be perforated, or *umbilicated*, *e. g.* *Solarium* (lxvi, 34). The perforation may be a mere chink, or fissure (*rima*), as in *Lacuna* (lxix, 32); or it may be filled up by a shelly deposit, as in many *Naticas* (lxiii, 45). In other shells, like the *Triton*, the whorls are closely coiled, leaving only a pillar of shell, or *columella*, in the centre: such shells are said to be *imperforate*. The name

columella, however, is usually applied to that portion of the inner wall of the shell which invests the axis—whether it be solid or open: it therefore is the lower portion of the inner margin of the aperture in most spiral shells. It is wanting in discoidal shells (*Planorbis*), hidden or minute in convolute shells (*Bulla* and *Cypræa*) and in ear-shaped shells (*Haliotis*). Non-spiral shells have no columella.

The *apex* or posterior end of the shell presents important characters, as it was the *nucleus* or part formed in the egg; it is sinistral in the *Pyramidellidæ*, oblique and spiral in the *Nucleobranchs* and *Emarginulæ*, and mammillated in *Turbinella pyrum* and *Fusus antiquus*.

The apex is directed backwards in all except some of the *Patellidæ*, in which it is turned forwards, over the animal's head. In the adult condition of some shells the apex is always truncated (or *decollated*) as in *Cylindrella* and *Bulimus decollatus*; in others it is only truncated when the animals have lived in acidulous waters (*e. g.* *Cerithidea* and *Pirena*), and specimens may be obtained from more favorable situations with the points perfect.

A *whorl* measures a single complete revolution of the spiral cone; its *periphery* is an imaginary spiral upon the outer wall, half-way between the suture and base: line of greatest width. In counting the number of whorls in a shell commence with the aperture-margin, whence, to a point on the suture of the volution above it constitutes one whorl; repeat this process to the apex.

The line of channel formed by the junction of the whorls is termed the *suture*.

The last turn of the shell ending with the aperture (*body-whorl*), is usually very capacious; the others are collectively called *spire-whorls*. In the females of some species the whorls enlarge more rapidly than in the males (*e. g.* *Buccinum undatum*). The *base* or anterior extremity of the shell is the opposite end to the apex, and is usually the front of the aperture.

The distance between the apex and base of a gastropod shell is termed its *height*. It has usually been called *length*, but the other designation corresponds better with the terminology of the lamellibranchiates as well as the non-spiral gastropods: thus in *Patella*, the distance from summit to base is *height*, from anterior to posterior margin is *length*, from side to side is *breadth*. In spiral shells the *breadth* or *diameter* is the distance across the body-whorl at its periphery.

The aperture is *entire* in most of the vegetable feeders (holostomata), but notched or produced into a *canal*, in the carnivorous families (siphonostomata); this canal surrounds a siphon, which is respiratory in its office, and does not necessarily indicate the nature of the food. Sometimes there is a posterior channel or canal, which is excurrent, or anal, in its function (*e. g.* *Strombidæ*

and *Ovulum volva*); it is represented by the slit in *Scissurella*, the tube of *Typhis*, the perforation in *Fissurella*, and the series of holes in *Haliotis*.

The margin of the aperture is termed the *peristome* (less frequently *peritreme*); sometimes it is continuous or entire (*Cyclostoma*), or becomes continuous in the adult (*Carocolla*); very frequently it is interrupted, the left side of the aperture being formed only by the body-whorl. The right side of the aperture is formed by the outer lip (*labrum*), the left side by the inner or columellar lip (*labium*), or partly by the body-whorl [termed the "wall of the aperture" (*parietal wall*), by Pfeiffer].

The aperture is descending, deflected, when it does not follow the spiral of the shell, but turns downwards. This occurs in many shells, *Helix*, etc.

Sometimes it departs from contact with the preceding whorl, as frequently in *Cylindrella*.

The aperture is:—

Longitudinal, when its greatest diameter is parallel with the axis of volution.

Transverse, reverse of longitudinal.

Oblique, greatest diameter oblique to the axis.

Circular, rotundate, orbicular.

Rounded, the circle slightly interrupted.

Auriform, ear-shaped, as in *Auricula*.

Ovate, egg-shaped.

Oblong, much longer than wide, rounded above and below.

Lunate, semilunar, semicircular. *Nerita*.

Triangular. *Janthina*.

Linear, narrow. *Cypræa*, *Conus*.

Quadrate. *Solarium*.

It is *patulous* when dilated and *compressed* when diminished at its entrance.

The outer lip is usually thin and sharp in immature shells, and in some adults (*e. g.* *Helicella* and *Bulimulus*); but more frequently it is thickened, or *reflected*; or curled inwards (*inflected*), as in *Cypræa*; or expanded, as in *Strombus*; or digitate, as in *Pteroceras*; or fringed with spines (*foliated*), as in *Murex*. The lip is *emarginate*, when incised or slit, as in *Pleurotomaria* (lxxxii, 84); *effuse*, when the basal or anterior extremity is slightly produced, depressed or reflected, as in *Melania*; *sinuous*, as in the sigmoidal margin in *Janthina*. Interiorly it may be *dentate*, *Nerita* (lxxviii, 56); *plicate* or *lamellate*, when the teeth become rib-like; *ringent*, having numerous large plications, nodules or teeth, *Scarabus*; *sulcate*, when grooved within; and *labiate* or *marginate*, when callously thickened near the margin.

Sculpture or color-markings upon the shell are *longitudinal*

when taking the direction of the axis, and *revolving* (or less properly *transverse*) when they follow the spiral. In the latter case they are also sometimes spoken of as *longitudinal*, with reference to the whorls only and not to the entire shell; but to avoid confusion it is becoming usual to consider their direction with reference to the shell.

The following are the principal varieties of sculpture:—

Canaliculate, suture profoundly channeled.

Cingulate, encircled by revolving ribs.

Carinate, revolving sculpture prominent, sharp.

Sulcate, encircled by channels.

Plicate, costate, ribbed, sculpture longitudinal.

Nodosely, tuberculately, granosely plicate, when the ribs are broken up into tubercles or granules; mostly caused by the intersection of revolving sculpture.

Striate, covered by fine close lines, either longitudinal or revolving.

Punctate, pitted.

Frequently punctate-striate are combined, as in *Mitra*.

Granulate, nodose, tuberculate, covered with nodules of small or large size, but not ribbed.

Muricate, spinous, echinate, when the nodules are sharp-pointed.

Decussate, cancellate, longitudinal and revolving sculpture crossing at right-angles.

Reticulate, sculpture not crossing at right-angles; irregularly decussated.

Clathrate, longitudinal and revolving lines both distant, forming a pattern somewhat like the iron bars of a prison window.

The last two terms are often used improperly as synonymous with decussate or cancellate.

Coronate, the upper part of the whorls having a series of revolving tubercles or spines.

Varicose, when the external thickening of the margin of the aperture occurring in some shells during rest-periods, is not absorbed away when growth is resumed, but remains, crossing the whorls at regular intervals.

THE OPERCULUM.

This is present in most gastropod mollusca, particularly in those provided with spiral shells; it also occurs in the larval stage of many nudibranchiate and opisthobranchiate mollusks, which are then provided with a temporary shell. The pulmoniferous land and fresh-water gastropods are inoperculate.

At the ending of the columellar muscle in the dorsum of the

foot, its fibres are nearly vertical to the plane of the operculum, which usually appears to be immediately superimposed upon them: in *Buccinum*, however, Keferstein finds interposed a layer of long cylindrical epithelial cells, with mostly distinct nuclei, and long divided processes entering between the muscular fibres.

The operculum, a cuticular development of these cells, is composed, as may be seen in the corneous opercula of *Murex*, *Purpura*, *Triton*, etc., of very thin superimposed layers. With the microscope one may perceive in a thin section, the cylindrical cells with their head attached to the lowermost layer; or, on the inner face, the small rounded pittings where they have been attached.

Homologies of the Operculum. Dr. J. E. Gray was, after Adanson, the first investigator who considered the operculum homologous with the right valve of the lamellibranchiates or bivalve mollusks. He has shown that the operculum is developed on the embryo long before it is hatched; that it is placed on and covers a particular part of the body called the *lobus operculigerus* and which bears to it the same relation which the mantle does to the shell, and that its growth occurs in the same manner; that this growth is made by the addition of new matter to the inner surface and especially near the margin; that it is attached to the animal by means of one or more muscles, which, as in the bivalve shell, pass from the larger valve or shell to the smaller one or operculum; that the operculum, as it increases in size, is gradually moved on the end of its muscle—the many-whorled operculum of the *Trochi* revolves as many times on the end of the muscle as the many-whorled spiral shell turns on its imaginary axis; that the operculum is often lined internally with a shelly coat like a shell, and sometimes, like the Cowries, its outer surface is covered also with a shelly deposit by a special development of the opercular lobe.

The principal difference between the operculum and the valve or shell of the gastropods consists:—

1. In the operculum having no cavity, its cone being depressed, flat or even concave, or very much compressed, forming only a spiral ribband, as in the spiral operculum. But this absence of a cavity is a difference only of degree, for the valves of some gastropods, as *Umbrella*, *Patella*, etc., are much flattened; the first resembling the annular operculum of *Ampullaria* and *Paludina*; but the greatest resemblance is to be observed in the small, flat valves of *Gryphæa*, *Exogyra*, *Chama*, and other genera of bivalve shells which are attached by one of their valves. These valves are often quite as flat and destitute of any cavity as the operculum of any gastropod; and it is to be remarked that these valves exactly resemble a spiral operculum in shape, the remains of the ligament forming a spiral mark on the outer

surface, showing how the valve has rotated on the body of the animal as the operculum rotates on the foot of the gastropods.

2. The operculum is generally horny and formed of a substance similar to the epidermis of shells; but then some shells, like the *Bulla*, *Aplysia*, certain *Uniones*, etc., are entirely or almost destitute of calcareous matter, and some of the helices, when inhabiting granitic regions, are equally of epidermal substance: on the other hand many opercula are thickened internally with a calcareous deposit.

Dr. Gray proceeds to show that in bivalve shells like *Chama*, where one valve (the attached one) has a spiral apex, whilst the other valve is a flattened spire, the position of the hinge with reference to the spire must rotate slowly with growth, as in the spiral operculum in its growth. The direction of the spire of a spiral operculum is opposite that of the shell, showing another analogy.

The conclusion arrived at by Dr. Gray is that the normal or typical form of mollusks is that protected by two valves or shells.

Dr. Gray has always maintained that the opercula are of great value in the distinction of genera, and he does not fail to condemn severely the practice of preserving shells in museums, or of figuring and describing them in conchological works, without opercula. I have already alluded to the supposed opercular bodies found with the fossil *Ammonites*: it may be added that they occur as well in some of the *Heteropods* and *Pteropods*.

In 1847, Lovén proposed to consider the operculum as analogous to the byssus; but Dr. Gray has pointed out that some genera of gastropods provided with an operculum, secrete a byssus also (*Rissoa*, *Cerrithium*, *Littorina*, etc.). However, Prof. Huxley, one of the latest and best authorities, thus endorses Lovén's views, which are now generally adopted:

"On the hæmal aspect of the posterior portion of the foot, a chitinous or shelly plate, termed the operculum, may be developed. This operculum appears to be the analogue, if not the homologue, of the byssus of the lamellibranchs; and is certainly not homologous with either of the valves of the shell of the latter, which are pallial structures."—HUXLEY, *Anat. of Invert.*, 487, 1877.

The following note by Dr. Gray, will throw some light on this very interesting subject:

"On the reproduction of the lost part of an operculum, and its probable restoration when entirely destroyed."

"It is to be expected that the operculum of a gastropodous mollusk may be sometimes broken or injured, but I have never hitherto been able to find any very distinct example of the kind, so as to study how the repair of the lost part would be effected.

That such an occurrence would most probably be rare, is easily explained from its situation, as the operculum is protected by the last whorl of the spire of the shell when the animal is expanded, and by the mouth when it is contracted into the cavity of the shell.

"I have lately met with a very distinct example in a specimen of *Fusus* in the British Museum collection. In this specimen the apical half of the operculum has been broken off and the lost part has been renewed by an irregular roundish process, nearly of the size of the lost part, not quite as thick as the original portion, and formed of rather irregular horny plates; the smaller or first-formed portion being in the centre of the broken line, so that the restored part bears some similarity to the annular operculum of a *Paludina*. This restoration is exactly like that which would have taken place in a shell under similar circumstances, and is a further proof of the truth of the theory which I have long advocated, that the operculum is a rudimentary valve, and is homologous to the second valve of the bivalve mollusks.

"In examining two specimens of *Pleurotoma babylonica*, preserved in spirits, with the opercula attached, I was much surprised to observe that the opercula of the two specimens were exceedingly different in structure and belonged to two distinct modifications of that valve, one being subannular, with the nucleus apical, like the other species of the genus, and the other annular, with the nucleus subcentral, somewhat like the operculum of *Paludina*. The examination of the restoration of the lost half of the operculum of the *Fusus* before referred to has solved the difficulty, and I have no doubt that one of these animals had by some accident lost its operculum, and that it had gradually restored it; commencing, as in the case of the restored part of the operculum of the *Fusus*, by a small nucleus in the centre of the opercular mantle, on the back of the foot, and gradually adding new layers around the edge of it, until it formed an annular operculum nearly of the size of the original, but differing from it in shape, being less acute in front and nearly similar in form at the two ends. A more minute examination has strengthened this theory, for the operculum of this specimen is less regularly developed than is usual in the annular operculum of the kind, and is much thinner than the normal operculum of the genus, as is the case in both these particulars with the restored part of the operculum of the *Fusus*.

"This change in the formation of the operculum when it is reproduced is just what might have been expected. The animal, when it has to form the operculum at its birth, begins its formation at the tip, and increases its size, as the animal requires a larger operculum for its protection, by the addition of new

layers to the outer edge of its larger and last-formed end; but when it has to reproduce this organ, the opercular mantle having reached a certain size, it proceeds to cover its surface with a new protection in the most easy and rapid manner, and, commencing from a more or less central spot on the surface, enlarges the surface covered by adding new matter to the entire circumference of the first-formed part; it continues this process without waiting to make the operculum as thick and solid as the one which was lost, until it reaches the size of the original, moulding itself on the opercular mantle, and adapting its form to the form of the throat of the aperture of the shell which it has to close. The change of form in the front of the restored and mended operculum is caused by the parts being moulded on the existing opercular mantle—consequently they have not the narrow front part which is found in the normal form caused by that part having been formed when the animal had this part of a small size; and as it increases in size the whole opercular mantle moves forward, leaving the small tip of the operculum free, and useless to the animal, and, therefore, not necessary to be reproduced when the operculum is re-formed in the adult age of the animal.”

The *operculum* presents modifications of structure which are so characteristic of the subgenera as to be worthy of particular notice. It consists of a horny layer, sometimes strengthened by the addition of calcareous matter on its exterior. Its inner surface is marked by a muscular scar, whose lines bear no relation to the external lines of growth, and its form is unlike the muscular scar in the shell. It is developed in the embryo, within the egg, and the point from which it commences is termed the nucleus; many of the spiral and concentric forms fit the aperture of the shell with accuracy, the others only close the entrance partially, and in many genera, especially those with large apertures (*e. g.* *Dolium*, *Cassidaria*, *Harpa*, *Navicella*), it is quite rudimentary or obsolete.

The operculum is described as—

Concentric, when it increases equally all round, and the nucleus is central or subcentral, as in *Paludina* and *Ampullaria* (lxxiv, 16).

Imbricated, or lamellar (ii, 35), when it grows only on one side, and the nucleus is marginal, as in *Purpura*, *Phorus*, and *Paludomus*.

Claw-shaped, or unguiculate (ii, 34), with the nucleus apical or in front, as in *Turbinella* and *Fusus*; it is claw-shaped and serrated in *Strombus* (iii, 49).

Spiral, when it grows only on one edge, and revolves as it grows; it is always sinistral in dextral shells.

Paucispiral, or few-whorled (ii, 37), as in *Littorina*.

Subspiral, or scarcely spiral, in *Melania* (lxxi, 15).

Multispiral, or many-whorled (ii, 36), as in *Trochus*, where they sometimes amount to twenty; the number of turns which the operculum makes is *not* determined by the number of whorls in the shell, but by the curvature of the opening, and the necessity that the operculum should revolve fast enough to fit it constantly. (Moseley).

Articulated, when it has a projection, as in *Nerita* (ii, 38).

Radiated is a modification of the articulated operculum in which the spiral is not so evident. *Navicella* (lxxviii, 78).

Too much importance, however, must not be attached to this very variable plate, as an aid to classification; it is present in some species of *Voluta*, *Oliva*, *Conus*, *Mitra*, and *Cancellaria*, but absent in others; it is (indifferently) horny or shelly in the different species of *Ampullaria* and *Natica*; in *Paludina*, it is concentric, whilst in the nearly related *Paludomus* it is lamellar, and in *Cerithium* it is either multispiral or paucispiral. The epiphragm or temporary plate with which pulmoniferous land snails close the aperture of the shell during hibernation may be distinguished from the true operculum by its homogeneity and want of growth-marks.

The operculum is large and well developed in *Concholepas Peruvianus*, a large species of *Purpuridæ* having a shell limpet- or rather haliotus-like in its greatly expanded aperture and body-whorl and comparatively small spire. The animal, like the limpets adheres firmly by the suction of its foot to rocks, so that an operculum is in this case an entirely useless appendage—yet it is always present.

“The majority of the individuals of *Volutharpa ampullacea* are without opercula, even without a trace of the pad-like gland or area from which the operculum is secreted. About ten per cent. of the individuals of the var. *acuminata* which I have examined had traces of this gland or area, marked by its smooth and rather whitish surface on the granulous dark slate-colored foot. About fifteen per cent. had well-developed opercula in the proper position. I have ascertained the same to be the case with regard to the typical form, from alcoholic specimens, collected by Dr. William Stimpson in Behring's Strait. There is no mistake about this, strange as it may and must appear, that different individuals of the same species are indifferently operculate or inoperculate.

A careful examination of this appendage reveals some singularities in it worthy of note. At first the operculum is of an ovoid form, with the nucleus near the edge at the larger end, and increases by additions around the edge, but principally upon the smaller or upper end. However, at some late period of its growth it takes a new start, and, seemingly, a new operculum

is commenced underneath the old one, with a central nucleus which increases by annular additions, and finally has its edges very much thickened and turned upward, giving it a saucer-like appearance, while the old operculum seems as if laying upon the saucer, with its nucleus and some of the adjacent portion projecting over the edge anteriorly. It has in all a diameter of .1 inch. That its form is not due to an individual abnormality is evident from the fact that all the specimens examined were similar."—W. H. DALL, *Am. Jour. Conch.*, vii, 106.

Mr. Gwyn Jeffreys, in his excellent "*British Conchology*," records the occurrence, upon the Kentish and Sussex Coasts, of *Buccinum undatum*, having two or three opercula. "In a bioperculate specimen, procured by Mr. Rich, one of the opercula is conical and borne on a cylindrical, stalk-like lobe, the other being of the usual shape; in a second specimen, one operculum is longitudinally oval, with the nucleus nearly terminal (as in *Fusus*), the fellow operculum being placed at a right-angle to it."

The duplication of opercula in *Buccinum undatum* appears to be paralleled by that of the internal horny pens or shells sometimes occurring in the cephalopod genus *Loligo*.

"The above facts," says Dr. Paul Fischer, "modify considerably our confidence in specific and generic characters furnished by the operculum. They at least demonstrate that the absence of an operculum will not suffice for the exclusion of mollusks from families the other genera of which are provided with them." *Jour. de Conch.*, 114, 1875.

The Pelecypoda, or lamellibranchiata differ widely from the two preceding great classes of mollusca in their shells. These are always present, and always external, and always bivalve (with sometimes small accessory pieces upon the hinge, as in *Pholas*). The two great classes of the encephala on the contrary are sometimes entirely without a testaceous envelope, and sometimes they possess it internally only; but in most cases it is present, external, and is usually univalve (in *Chiton* composed of eight plates). Bivalve mollusca are all aquatic, and except a very few genera, marine. In genera and species they are much less numerous than the gastropoda, the proportion being about one-third, but in individuals they are relatively much more numerous.

In their native element the Oyster and Scallop lie on one side, and the lower valve is deeper and more capacious than the upper. Most other bivalves live in an erect position, resting on the edges of their shells, which are of equal size. Those which move about much, like the river-mussel, maintain themselves nearly horizontally, and their keel-shaped foot is adapted for ploughing through sand or mud.

The burrowing species have a strong and stout foot with which they bore vertically into the sea-bed, often to a depth far

exceeding the length of their valves; these never voluntarily quit their abodes, and often become buried and fossilized in them. They most usually burrow in soft ground, but also in coarse gravel, and firm sands and clays; one small *Modiola* makes its holes in the cellulose tunic of *Ascidians*, and another in floating blubber.

The boring shell-fish have been distinguished from the mere burrowers, perhaps without sufficient reason, for they are found in substances of every degree of hardness, from soft mud to compact limestone, and the method employed is probably the same.

The means by which bivalves perforate stone and timber has been the subject of much inquiry, both on account of its physiological interest, and the desire to obtain some remedy for the injuries done to ships, and piers, and breakwaters. The ship-worm (*Teredo*) and some allied genera, perforate timber only; whilst the *Pholas* bores into a variety of materials, such as chalk, shale, clay, soft sandstone and sandy marl, and decomposing gneiss; it has also been found boring in the peat of submarine forests, in wax and in amber. It is obvious that these substances can only be perforated alike by mechanical means; either by the foot or by the valves, or both together, as in the burrowing shell-fish. The *Pholas* shell is rough, like a file, and sufficiently hard to abrade limestone; and the animal is able to turn from side to side, or even quite around in its cell, the interior of which is often annulated with furrows made by the spines on the front of the valves. The foot of the *Pholas* is very large, filling the great anterior opening of the valves; that of the ship-worm is smaller, but surrounded with a thick collar, formed by the edges of the mantle, and both are armed with a strong epithelium. The foot appears to be a more efficient instrument than the shell in one respect, inasmuch as its surface may be renewed as fast as it is worn away.

In the museum of the Academy of Natural Sciences of Philadelphia are specimens of *Pholas dactylus* from the coast of France imbedded in gneiss rock, much too hard to have been excavated by the valves of the shell; moreover the rough points of its sculpture show no signs of abrasion, which must surely have taken place if these delicate projections had been used to rasp the surrounding surface.

The mechanical explanation becomes difficult in the case of another set of shells, *Lithodomus*, *Gastrochæna*, *Saxicava*, and *Ungulina*, which bore into calcareous rocks, and attack the hardest marble, and still harder shells. In these instances the valves can render no assistance, as they are smooth, and covered with epidermis; neither does the foot help, being small and finger-like, and not applied to the end of the burrow. Their

power of movement also is extremely limited, their cells not being cylindrical, whilst one of them, *Saxicava*, is fixed in its crypt by a byssus. These shell-fish have been supposed to dissolve the rock by chemical means (Deshayes), or else to wear it away with the thickened anterior margins of the mantle (Hancock), or by the incessant action of the ciliæ of the mantle margin (Agassiz). All attempts to prove the use of an acid secretion in excavating have hitherto failed, as might be expected; for the hypothesis of an acid solvent supposes only a very feeble but continuous action, such as in nature always works out the greatest results in the end.

The holes of the *Lithodomi* often serve to shelter other animals after the death of the rightful owners; species of *Modiola*, *Arca*, *Venerupis*, and *Coralliophaga*, both recent and fossil, have been found in such situations, and mistaken for the real miners.

The boring bivalves have been called "stone-eaters" (*lithophagi*), and "wood-eaters" (*xylophagi*), and some of them at least are obliged to swallow the material produced by their operations, although they may derive no sustenance from it. The ship-worm is often filled with pulpy, impalpable sawdust, of the color of the timber in which it worked (Hancock). No shell-fish deepens or enlarges its burrow after attaining the full growth usual to its species.

Between the bivalve mollusks having *attached* valves, as in the oyster, and those which are *free*, as in *Cardium*, *Lucina*, *Tellina*, the fresh-water mussel, etc., are placed not only those in which the liberty of the animal is circumscribed by its living in a burrow, self-immured for life in a cell; but also those which spin a *byssus* (iii, 40), by which the shell is attached to some foreign substance, from which the individuals of the species usually depend in clusters or colonies. Usually byssus-spinners, as the *Modiolas*, *Mytilus*, or sea-mussel, are inhabitants of shore lines, in situations where, at low tide they are exposed above the waters; they are thus subject to the wash and lifting power of the incoming waves, and but for their anchor-like fastenings would be torn away from their haunts, dispersed, and frequently destroyed—as most free shells are in similar situations.

The *valves* of the *Conchifera* are bound together by an elastic *ligament* (ii, 31), and usually articulated by a *hinge* furnished with interlocking teeth (*ibid.*). The shell is closed by powerful adductor muscles (*ibid.*), but opens spontaneously by the action of the ligament, when the animal relaxes, and after it is dead.

Each valve is a hollow cone, with the apex turned more or less to one side; the apex is the point from which the growth of the valve commences, and is termed the *beak*, or *umbo* (*ibid.*). The beaks (*umbones*) are near the hinge, because that side grows least

rapidly, sometimes they are quite marginal; but they always tend to become wider apart with age. The beaks are either straight, as in *Pecten*; curved, as in *Venus*; or spiral, as in *Isocardia* and *Diceras*. In the latter case each valve is like a spiral univalve, especially those with a large aperture and small spire, such as *Concholepas*; it is the left valve which resembles the ordinary univalve, the right valve being a left-handed spiral like the reversed gastropods. When one valve is spiral and the other flat, as in *Chama*, the resemblance to an operculated spiral univalve becomes very striking.

In order to properly understand the relation of the bivalve shell to its owner, and thus obtain a clearer idea of the nomenclature employed in measurements, we should suppose a living lamellibranchiate to be creeping upon the sea-bed, its line of march directed from us. The shell will then be elevated, the ligament or hinge-margin uppermost, the opposite margin whence the foot protrudes lowest; these are then termed the dorsal and ventral margins respectively, and the distance between them is the height of the shell. I use dorsal margin in preference to beaks as a point of measurement, because in some mollusks, such as *Mytilus*, the beaks are at the anterior end: it is difficult to so locate the measurements as to suit all forms of shells. The hinge-line then indicates the direction of the length of the shell, and the actual length is the distance between the anterior and the posterior (or collectively lateral) margins. The breadth is a diameter transverse to the length, and includes the distance between the greatest exterior convexity of each valve. The thickness refers to the distance included between the internal and the external face of a valve. When the animal travels from us in this manner, hinge-line uppermost, the beaks are usually nearer to, and their apices directed forwards towards the anterior end, or the direction of march; whilst the ligament binding the valves together is posterior to the beaks, or nearest the observer. The valves lying on the right and left sides of the hinge-margin, when the shell is thus placed, are respectively termed right valve and left valve.

As the shell lays before us in the study, the valves may be thus distinguished; place the dorsal margin from you, the ventral margin towards you, the exterior surface exposed; if the ligament is on the left side, you have the right valve, and if on the right side, the left valve. There is frequently a *lunule* (ii, 31), or small semicircular impression anterior to the beaks; when this appears on the right side, the valve is right, and *vice versa*. If the interior of the valve is placed uppermost, the dorsal margin from us, the ventral margin towards us, we look first for a sinus or flexure (ii, 31) of the pallial impression, a mark made by the retractor of the siphons; if on the left side, the

valve is left, and *vice versa*. Sometimes also there are posterior lateral teeth or laminae of the hinge-margin which are found on the right or left side, according as the valve is right or left. When these distinguishing marks of the interior are absent, the valves can be more readily determined externally.

In monomyary and attached shells it is sometimes difficult to distinguish the valves. The single muscular scar is on the posterior side of the interior, and in *Pecten*, the *byssal sinus* is below the *ear* on the anterior side (ii, 32).

Linnaeus and the naturalists of his school described the front of the shell as the back, the left valve as the right, and *vice versa*. In those works which have been compiled from "original descriptions" (instead of specimens) sometimes one end, sometimes the other, is called *anterior*; and the *length* of the shell is sometimes estimated in the direction of the length of the animal, but just as frequently in a line at right-angles to it.

The conchifera are mostly equivalve, the right and left valves being of the same size and shape, except in the *Ostreidæ* and a few others. In *Ostrea*, *Pandora*, and *Lyonsia*, the right valve is smallest; in *Chamostrea* and *Corbula*, the left; whilst the *Chamaceæ* follow no rule in this respect.

The bivalves are all more or less *inequilateral*, the anterior being usually much shorter than the posterior side. *Pectunculus* is nearly equilateral, and in *Glycimeris* and *Solemya* the anterior is much longer than the posterior side. The ligament is sometimes between the umbones, but is never anterior to them.

Bivalves are said to be close, when the valves fit accurately, and gaping, when they cannot be completely shut. In *Gastrochæna* the opening is anterior, and serves for the passage of the foot; in *Mya* it is posterior and siphonal; in *Solen* and *Glycimeris* both ends are open. In *Byssosarca* there is a ventral opening formed by corresponding notches in the margin of the valves, which serves for the passage of the byssus; in *Pecten*, *Avicula*, and *Anomia* the byssal notch (or sinus) is confined to the right valve.

The surface of bivalve shells is often ornamented with ribs which *radiate* from the umbones to the margin, or with *concentric* ridges, which coincide with the lines of growth. Sometimes the sculpturing is oblique, or wavy; in *Tellina fabula* it is confined to the right valve. In many species of *Pholas*, *Teredo*, and *Cardium*, the surface is divided into two areas by a transverse furrow, or by a change in the direction of the ribs. The lunule (ii, 31), is an oval space in *front* of the beaks; it is deeply impressed in *Cardium retusum*, L., *Astarte excavata*, and the genus *Opis*. When a similar impression exists behind the beaks, it is termed the *escutcheon*.

The *ligament* of the Conchifera forms a substitute for the

muscles by which the valves of the Brachiopoda are opened. It consists of two parts, the ligament properly so-called, and the cartilage; they exist either combined or distinct, and sometimes one is developed and not the other. The external ligament is a horny substance, similar to the epidermis which clothes the valves; it is usually attached to ridges on the posterior hinge-margins, behind the umbones, and is consequently stretched by the closing of the valves. The ligament is large in the river-mussels, and small in the *Mactras* and *Myas*, which have a large internal cartilage; in *Arca* and *Pectunculus* the ligament is spread over a flat, lozenge-shaped area, situated between the umbones, and furrowed with cartilage grooves. In *Chama* and *Isocardia* the ligament splits in front, and forms a spiral round each umbo. The *Pholades* have no ligament, but the anterior adductor is shifted to such a position on the hinge-margin that it acts as a hinge-muscle.

The internal ligament, or *cartilage*, is lodged in furrows formed by the ligamental plates, or in pits along the hinge-line; in *Mya* and *Nucula* it is contained in a spoon-shaped process of one or both valves. It is composed of elastic fibres placed perpendicularly to the surfaces between which it is contained, and is slightly iridescent when broken; it is compressed by the closing of the valves, and tends forcibly to open them as soon as the pressure of the muscles is removed. The name *Amphidesma* (double ligament) was given to certain bivalves, on the supposition that the separation of the cartilage from the ligament was peculiar to them. The cartilage-pit of many of the *Anatinidæ* is furnished internally with a movable ossicle.

The ligament is frequently preserved in fossil shells, such as the great *Cyprinas* and *Carditas* of the London Clay, the *Unios* of the Wealden and even in some lower Silurian bivalves.

All bivalves are clothed with an *epidermis* which is organically connected with the margin of the mantle. It is developed to a remarkable extent in *Solemya* and *Glycimeris*, and in *Mya* it is continued over the siphons and closed mantle-lobes, making the shell appear internal.

The interior of bivalves is inscribed with characters borrowed directly from the shell-fish, and affording a surer clue to its affinities than those which the exterior presents. The structure of the hinge characterizes both families and genera, whilst the condition of the respiratory and locomotive organs may be to some extent inferred from the muscular markings.

The margin of the shell on which the ligament and teeth are situated, is termed the *hinge-line* (ii, 31). It is very long and straight in *Avicula* and *Arca*, very short in *Vulsella*, and curved in most genera. The locomotive bivalves have generally the strongest hinges, but the most perfect examples are presented

by *Arca* and *Spondylus*. The central teeth, those immediately beneath the *umbo*, are called hinge (or *cardinal*) teeth (ii, 31); those on each side are *lateral* teeth (*ibid.*). Sometimes lateral teeth are developed, and not cardinal teeth (*Kellia*): more frequently the hinge-teeth alone are present (*Alasmodon*). In young shells the teeth are sharp and well defined; in aged specimens they are often thickened, or even obliterated by irregular growth (*Hippopodium*) or the encroachment of the hinge-line (*Pectunculus*). The dentition of bivalve shells may be stated thus:—cardinal teeth, 2·3 or $\frac{2}{3}$ —meaning 2 in the *right* valve, 3 in the *left*; lateral teeth 1—1, 2—2, or 1 anterior and 1 posterior, in the *right* valve, 2 anterior and 2 posterior lateral teeth in the *left* valve. Many of the fixed and boring shells are *edentulous*.

The *muscular impressions* are those of the adductors, the foot and byssus, the siphons, and the mantle (ii, 30, 31).

Fossil bivalves are of constant occurrence in all sedimentary rocks; they are somewhat rare in the older formations, but increase steadily in number and variety through the secondary and tertiary strata, and attain a maximum of development in existing seas.

Some families, like the *Cyprinidæ* and *Lucinidæ* are more abundant fossil than recent; whilst many genera, and one whole family (the *Hippuritidæ*), have become extinct. The determination of the affinities of fossil bivalves is often exceedingly difficult, owing to the conditions under which they occur. Sometimes they are found in pairs, filled up with hard stone; and frequently as casts, or moulds of the interior, giving no trace of the hinge, and very obscure indications of the muscular markings. Casts of single valves are more instructive, as they afford impressions of the hinge.

Another difficulty arises from the frequent destruction of the nacreous or lamellar portion of the fossil bivalves, whilst the cellular layers remain. The *Aviculidæ* of the chalk have entirely lost their pearly interiors; the *Spondyli*, *Chamas*, and *Radiolites* are in the same condition, their inner layers are gone and no vacancy left, the whole interior being filled with chalk. As it is the inner layer alone which forms the hinge, and alone receives the impressions of the soft parts, the true characters of the shells could not be determined from such specimens. Our knowledge of the extinct *Radiolite* is derived from natural moulds of the interior, formed before the dissolution of the inner layer of shell, or from specimens in which this layer is replaced by spar.

The necessities of geologists have compelled them to pay very minute attention to the markings in the interior of shells, to their microscopic texture, and every other available source of comparison and distinction. It must not, however, be expected

that the entire structure and affinities of molluscos animals can be predicated from the examination of an internal mould or a morsel of shell, any more than that the form and habits of an extinct quadruped can be inferred from a solitary tooth or the fragment of a bone.*

“Who has not admired the beauty of shells?” exclaims Carpenter,† “the rich lustre of the Cowries; the glossy polish of the Olives; the brilliant painting of the Cones; the varied layers of the Cameos; the exquisite nacre of Mother-of-pearl? Who has not listened to the mysterious ‘sound of the sea’ in the Whelks and Helmets, or wondered at the many chambers of the Nautilus? What child ever went to the sea-shore without picking up shells; or what lady ever spurned them as ornaments of her parlor? Shells are at once the attraction of the untutored savage, the delight of the refined artist, the wonder of the philosophic zoologist, and the most valued treasures of the geologist. They adorn the sands of sea-girt isles and continents now; and they form the earliest ‘footprints on the sands of time’ in the history of our globe.”

CARTILAGES.

Mollusks have no internal skeleton comparable to that of the Vertebrata, but in the Cephalopoda the most active and highly organized of the mollusca are found cartilaginous supports for some of the organs, partially replacing the vertebrate skeleton. Those of the principal nerve-gangliæ are well developed, sometimes completely enveloping them; besides which the principal organs of sense, the valves of the mantle, the fins, etc., are duly provided.

As might be expected from its habits, the cartilaginous system of the Nautilus is the most simple of all the cephalopods, consisting of a well-developed head-cartilage, so shaped and situated as to support the œsophageal ring, the cerebral and pedal commissures, whilst two prolongations of it serve the funnel or siphon.

In the dibranchiata, unlike the Nautilus, the head-cartilage forms a complete ring around the œsophagus; from the medial line of the back of this ring spring two lancet-form cartilaginous processes, the cartilages of the eyelid, and the under side of the same ring spreads into a spoon-shaped process which comes far forward and supports the eyes; particularly when, as in Sepia, it reaches to the sides of the head and encompasses the ocular opening.

* *Etudes Critiques sur les Mollusques Fossiles*, par L. Agassiz, Neuchâtel, 1840.

† *Lectures on Mollusca*, Smithsonian Report, 1860.

The cartilages of the back and of the fins are shown in position in Plate liii, 47, after Keferstein, of *Sepia officinalis*. In the Loligos the moon-shaped cartilage of the back is wanting, but is replaced in its functions by the upper end of the corneous pen or inner shell. In the octopods there remain only of this back-cartilage its two narrow posterior blade-like projections (*d*, same fig.). In the genus *Cirroteuthis* (iv, 58), the dorsal cartilage is very broad, so as to simulate the internal shell or pen of the decapod. At the entrance of the anterior ventral mantle opening is found a singular cartilaginous mechanism, which d'Orbigny has called the "appareil de résistance," peculiar to the Cephalopoda, which consists of buttons or ridges and corresponding grooves placed on the opposed inner sides of the mantle and the body, and by which the animal may at will button its head to the mantle to prevent the injury which might otherwise result to it during a struggle with wave or prey, in consequence of its want of support there (iv, 57). On the other hand, by relaxing this support the animal preserves for itself a freedom of movement of head and arms which would be impracticable were these as permanently and closely connected with the body on the ventral as they are on the dorsal side. The arrangement of this resisting apparatus varies in different genera, and is a good distinctive character: largely developed in those species which have no fixed attachment to the body, as in *Ommastrephes*, *Loligo*, etc., it exists also in those genera which possess only a very small cervical band of attachment, as in *Argonauta*, but it is wanting in those genera in which the permanent bands are well developed, as in *Octopus*, *Cranchia*, etc.

In *Philonexis* or *Tremoctopus*, a button is found at the base of the siphon tube, with a corresponding groove to receive it upon the inner wall of the mantle, but in *Argonauta* the relative position of button and buttonhole is reversed. In *Rossia* we find a short ridge surmounted by a profound groove opposed to an elongated groove on the base of the siphon; in *Loligo* and *Sepioteuthis*, the ridge is somewhat longer, without grooves; in *Onychoteuthis* and *Enoploteuthis* the ridge is nearly half the length of the body, with the siphonal groove; in *Sepia* an oblique oblong button can be fixed into a similarly formed pit upon the siphon; in *Chiroteuthis* there are an oblong longitudinal button and two lateral pits fitting into a central pit and two buttons on the siphon; finally, in *Ommastrephes*, in which it is most complicated, there are two projections, one oblong and the other triangular, entering cavities upon the siphonal tube, and two projections upon the latter which enter between the tubercles of the opposed mantle. The complexity of this attachment increases, it will be perceived, with the activity of the animal,

and in the comparatively sluggish littoral genera it is not found at all.

In the Gastropoda the cartilaginous internal supporting organs are reduced to two, or sometimes four small plates; they are found in the head, are more or less closely connected with one another, and are surrounded by the pharyngeal muscles. They form the supporting apparatus of the radula and the parts connected with it, and also afford points to which some of the pharyngeal and radular muscles are inserted (ix, 99).

MUSCLES, ARMS AND FINS IN THE CEPHALOPODA.

In *Nautilus* we distinguish the two adductor muscles, by which the animal attaches itself to the walls of its shell, and which are united by a horny collar; and within the shell itself we may notice on either side the impressions of these attachments, sunken into the pearly walls. On the outside of the head-cartilage and its projections towards the siphon is found another important muscle, that of the neck or collar, which resembles the cartilaginous neck-plate of the *dibranchiata*. Other strong muscles arise from the surface of the two siphon cartilages and form an organ more or less completely tubular—the *siphon* (xxiii, 9)—the important means of conducting the respired water when driven out from between the body and mantle by the contraction of the latter, and serving as a swimming organ also, by the same action performed with greater vehemence. In swimming, the aperture of the *funnel* or siphon is normally directed towards the head, and its discharges cause a series of rapid backward motions, but the animal is able at will to direct the stream to either side, and even to bend the anterior end of the siphon back upon itself to some extent, when it desires to vary the direction of its movement. In some genera a valve is developed within the funnel preventing the reflux of the water. The funnel is entire in the *dibranchiata*, but cleft in its length in the *Nautili*; upon its base is found, in the *decapod* genera, a portion of the curious stiffening processes (*appareil derésistance*) already spoken of. In *Onychoteuthis* and *Ommastrephes* the funnel is lodged in a special cavity in the under side of the head.

The so-called fins or swimming membranes, wanting to nearly all the *octopods* and the *Nautili*, exist in all *decapods*, in their various genera assuming distinctive forms which may occupy either the whole of the sides of the body (xxvii, 46) or only a portion thereof, and even extend behind into a sort of tail (xxvii, 44). These membranes in *Loligo*, *Ommastrephes* and in *Onychoteuthis* are formed of transverse muscular layers covered with a very thin epidermis, their surface striated by the muscular fibres beneath. These fins are not contractile, but invariable in form; they are firm and coriaceous, their edges are always entire

and very thin. In *Sepia* the membrane part is covered with a thick skin which extends beyond it. The firmness of the fins seems to be in direct relation to the habits of the species; thus the pelagic genera, encountered only on the high seas and possessing the power of darting to some height above the water, are furnished with the most coriaceous fins; whilst those of the littoral genera are of a softer consistence. Whilst these natatory lobes are of secondary importance as means of locomotion, they serve additionally as a parachute to preserve the position of the body in the water, and to vary the same according to the desire of the animal; their rapid undulation, commencing from the front or hind part, according to the direction in which the animal wishes to progress, is of course, of considerable aid in navigation.

The *arms* (xxvii, 48), are at once organs of locomotion, either by swimming or crawling, of touch and of prehension. In the tetrabranchiates they are multiplied in number but reduced in size and strength, being short, cylindrical, without cupules or sucking-disks, and retractile into distinct sacks (iv, 62); in the dibranchiates they are of definite number, namely *eight sessile* or non-retractile arms; with the addition of *two*, generally much longer, retractile, *tentacular arms* (xxvii, 48) in some of the genera; and these are all provided with suckers or organs of prehension.

The arms of the octopods (xxiii, 1) are longer, more fleshy and altogether better adapted to their creeping locomotion, and to reaching out from their rocky hiding-places to seize the passing prey; whilst the comparatively shorter arms of the decapods are compensated by the two generally very long, retractile *tentacles*, the swimming membrane, the more cylindrical narrow body, and the stiffening of the cuttle-bone or pen, in adapting them for their pelagic life.

The internal face of the arms is provided with *sucking-disks* or *cups* (xxiii, 4) intended to retain objects with which they may be brought in contact. The cups are sessile and fleshy only in the octopods, and they are pedunculated and then furnished with an internal corneous ring, armed with a serrated edge (xxv, 22), or with a corneous hook in the decapods (xxvii, 43).

In *Eledone* and *Cirroteuthis* the sessile cupules occupy a single median line on the arms, whilst in the other octopod genera they are in two or more parallel lines. In *Octopus* they are infundibuliform, shallow, with a depressed radiated surface. In *Argonauta* these cups are slightly narrowed at their base, and in *Philonexis* (*Tremoctopus*) they are cylindrical and extensible. The sessile suckers are powerful means of prehension; they act like cupping-glasses by the withdrawal of a central plug.

The pedunculated cupules of the decapods occupy alternately,

two lines in all the genera except *Sepia*, in which they are in four lines. Always very oblique, raised on a narrow excentric stalk, they are fleshy, marked externally by a thin margin which confines a corneous ring, in the middle of which is an elevated surface. The functions of these cupules compared to those of the octopods appear to differ in this respect, that they cannot hold by suction, being prevented by the thin border and corneous ring, but in lieu of this means of prehension they have the ring itself powerfully armed with recurved points, and greater facilities of attachment on account of having the cupules pedunculated and movable, instead of sessile as in the octopods. In a state of repose these formidable rings are covered by their fleshy borders; the latter are only contracted when their weapons are to be used.

Whilst the corneous circle or ring exists in all decapods, it is modified nevertheless in the different genera. *Enoploteuthis*, and the fossil *Belemnites* offer a curious modification of structure of the corneous ring, which has disappeared apparently, and is replaced by powerful recurved hooks, which are really the two halves of the ring applied closely together. These hooks are retractile or extensible at the will of the animal, and when retracted are totally enveloped with flesh—recalling the velvet cushion of the paw of a cat.

The tentacular arms or tentacles of the decapods, always arising from subocular sacks in the circle of sessile arms and between the third and fourth pairs of the latter, are entirely retractile in *Sepia*, in *Sepiola* and in *Rossia*, and only partially so in other genera. Very long (in *Chiroteuthis* six times the length of the body), they consist of a rounded or compressed stalk, generally without cupules, and an expanded and thickened extremity or *club*, armed with cupules upon its internal face. These cupules or hooks are very unequal in size and occupy four lines upon the club in *Loligo* and *Ommastrephes*, six in *Histioteuthis* and six or ten in *Sepia*, *Sepiola* and *Rossia*. *Onychoteuthis*, *Enoploteuthis*, *Celæno* and *Belemnites* have hooks, in two rows; and in the two former there is additionally a group of small cupules and tubercles at the base which may be used to form by the apposition of these parts in the two tentacles a sort of fleshy articulation and support for the action of the armed clubs. *Chiroteuthis* has an additional oval fleshy cupule at the extremity of the club.

The *web* which connects the arms in many of the cephalopods may be likened to an umbrella of which the arms themselves may represent the ribs. It is but little developed in some genera, but attains an enormous development in *Cirrosteuthis* (xxiii, 7), where it unites all the arms to nearly their tips; and in species

of Tremoctopus it is only developed between the dorsal or superior arms (xxiii, 8).

The modification of one of the sessile arms of the male Cephalopods for sexual purposes, causing it to assume a totally different appearance, will be more appropriately treated under sexual organs.

The tetrabranchiates, of which the Nautilus is an example, (iv, 62), develop a *sheath*, in the margin of which are digitations, eight in number, and from these digitations project in a double series, thirty-six small unarmed *brachial* tentacles, lamellated on their inner surface, and retractile at the will of the animal. This sheath expands greatly dorsally, forming a triangular, tuberculate, fleshy *hood*, by which the aperture of the shell may be closed in lieu of an operculum. In addition to the brachial there are other tentacles; namely, four groups of twelve or thirteen each, termed *labial*, and surrounding the lips, and four *ocular* tentacles, situated one in front and one behind each eye, and which appear to be organs of sensation. In the male there is some modification; the internal tentaculiferous lobes are wanting, and the external ones are divided into an anterior with eight and a posterior one with four tentacula. Upon the left side, moreover, the four posterior tentacles are modified into a peculiar hectocotyle termed a *spadix*, bearing a discoidal follicular gland upon its outer surface.

ORGANS OF MOVEMENT IN THE GASTROPODA, ETC.

Foot. The *foot* is a fleshy, expanded mass, forming the entire under side of the body, or attached to it in front of the mantle by a peduncle. In the heteropods, etc., the foot is divisible into three portions, termed, respectively, *propodium*, *mesopodium* and *metapodium*; but in most typical gastropods these three areas are blended in the sole, although the metapodium is indicated by the fact of its supporting on its dorsal side the operculum. In Strombus (iii, 49), a transverse furrow separates the mesopodium from the propodium, and the metapodium is covered downwards and in front by the operculum.

The peduncle of the foot, when differentiated, is usually short and depressed, and covers the under side of the body between the mantle collar and mouth, the foot being expanded forward, but more extensively backwards; but in Strombus and its allies the foot is slim and cylindrical. Haliotis, Patella and Chiton have the foot, on the other hand, very much expanded. Rapidity of motion appears to be in inverse ratio to the size of the foot; those genera in which the organ is enormously developed, especially in those just cited, where it occupies the entire ventral surface of the body, being slow in movement.

Frequently the anterior border of the foot is variously lobed

and these lobes are mostly of glandular structure, though Keferstein has found them in *Buccinum* to consist of interwoven meshes of muscular fibres, in which are lodged beautiful nucleated cells. These lobes or filiform processes, like those of the mantle, are tactile organs.

When the foot is greatly expanded, as in *Cymba*, *Harpa*, *Dolium*, etc., it is generally laterally recurved over the shell, somewhat like the mantle in *Cypræa* and *Marginella*. In *Oliva* (iii, 46), and in *Ancillaria*, the propodium, represented by triangular lobes, lies flat, while the distinctly separated mesopodium covers a portion of the sides of the shell. In *Natica* the propodium is greatly developed forwards, extending beyond the head and reflected backwards over the latter in such manner as to conceal it, with its tentacles, and the anterior part of the shell itself, from view (lxiii, 41). The mesopodium in *Natica*, being likewise largely reflected over the shell, the respiratory cavity is covered, but a canal is developed between the reflected propodium and the mesopodium, which conveys water to the branchiæ.

There is a rounded glandular opening in the sole of the foot of many gastropods (*Pyrula*, vii, 85), which is the external opening of the pedal aqueous vascular system; to be more particularly noticed hereafter.

Nearly all of the prosobranchiates whilst in the larval state support an operculum on the dorsal side of the metapodium; with some, the operculum is fugacious, being lost in the transformation of the animal, yet it continues present in most of the groups. The opercular mantle sometimes extends beyond the borders of the operculum itself, and is divided into processes or filaments, which may, as in *Ampullaria*, be reflected over it.

The foot is the organ of locomotion of univalve mollusks; the anterior portion is protruded, and then by means of wave-like muscular contractions of the sole, the whole mass of body and shell is brought forward—when the former motion is repeated. In *Phasianella*, and many other genera, the foot is divided lengthwise by a furrow, and when in motion the muscles of the sole are alternately used on either side, so that the effect of the motion is that of a pair of feet. In attached shells, like *Vermetus*, the foot is only rudimentary and serves merely as a support to the operculum.

In retiring within the aperture of the shell the foot is generally doubled upon itself across the middle, so that its dorsal posterior side, bearing the operculum, comes outermost; but in *Oliva* and *Voluta* it folds longitudinally, whilst the quadrate foot of *Conus* is withdrawn obliquely, without folding, first the right, and then the left side.

In the Scaphopoda the foot is vermiform (iii, 43).

Natatory Lobes. The heteropods or swimming gastropods develop from the ventral portion of their body a vertical fin or swimming disk (lxxxvi, 99), which, in the male only, is furnished with a sucker placed on its margin. Carinaria has also a caudal lobe or tail expansion for swimming.

Opisthobranchiate gastropods are furnished with lateral lobes proceeding from the sides of the anterior portion of the foot, or from the mantle; in Lobiger (lxxxix, 66), a pair of them is developed upon each side of the body.

The pteropods (xlii), develop a pair of dorsal swimming lobes, but the foot is small or obsolete in most of them. In Cleodora it is combined with the fins; in Spirialis a rudimentary foot supports an operculum.

The Columellar Muscle. There is but one attachment of the gastropod to its shell; namely, by means of the columellar muscle, by which the inner face of the columella is directly united with the posterior portion of the body of the animal. It passes underneath the mantle, greatly thickening the body wall, and terminates upon the inner face of the operculum, so that by its contractions the operculum and shell are approximated, and the animal withdrawn within the latter. The form of this muscle depends on that of the shell, and in the conical, non-spiral shells especially, varies greatly from its normal development. Thus it is horseshoe-shaped in Capulus (lxvi, 30); it is divided into two portions, one of which lies on either side of the anterior part of the animal, in Fissurella. In Haliotis the animal is coiled around it, and its insertion, instead of being on the columella, is on the middle of the inner wall of the shell itself, upon which it forms a large oval impression (lxxxiii, 11).

In the genus Clausilia an accessory spathuliform piece (*Clausilium*, iii, 42), is united to the columellar axis of the shell by an elastic pedicle, and appears to act as a *purchase* in assisting the columellar muscle, when the animal desires to withdraw within its shell.

ORGANS OF MOVEMENT IN THE PELECYPODA.

The foot (iii, 50, 52), is developed in most bivalve mollusks and is extremely flexible, having layers of circular muscular fibres for its extension, and longitudinal bands for its retraction. Its degree of development varies with the habits of the genera; in Pholas, Nucula, etc., it shows a sort of pedal disk, whilst in such genera as Unio, Venus, it is compressed and securiform; in Mycetopus it is very long and much dilated at its extremity; whilst in Lucina it is somewhat cylindrical, and in Mytilus tongue-like (iii, 40, 41). In the attached bivalves, such as Ostræa, it is either not developed or exists in a rudimentary state subsidiary to the glands which secrete the byssus.

In the burrowing species, the foot is large and powerful, and in some of those which excavate cells within hard substances, it is studded with siliceous spicula, which make it an efficient instrument for boring: although it is very doubtful whether this is the only or even the principal means by which the animal works.

Adductor Muscles. These attach the animal to the valves of the shell upon either side, and their contraction serves to close them together. Their insertion is shown by scars upon the valves (ii, 31, 32; iii, 51), and these indicate an important difference in position and in number, useful in the classification of bivalve mollusca. In the *Monomyaria* (ii, 32), the adductor is single and usually subcentral: *Ostræa*, *Tridacna*, etc., being examples; whilst in the *Dimyaria* (ii, 31), including most of the bivalves, there are two adductor muscles, situated anteriorly and posteriorly near the margin. The action of the adductors is antagonistic to that of the ligament which connects the valves of the shell, and which passively opens them. Their contraction is rapid and powerful, exerting a force which is enormous, when compared with their size and weight; according to the experiments of M. Leon Vaillant made at Suez, a *Tridacna*, 21 centimetres long, and the muscle of which weighed but 39 grammes, lifted a weight of 4914 grammes by its contraction. In *Pecten varius* (ii, 32), two large independent impressions are formed by the adductor, the muscle itself being composed of two elements; there is also in the left valve a third impression produced by the foot. So in *Anomia*, whilst the right valve has the single muscular impression only, the left valve shows three additional scars, the large central one being that of the muscle of the *plug* (the equivalent of the byssus of *Pinna* and *Modiola*), a smaller one within the umbo, and one in the disk being caused by the retractors of the foot. These foot retractors cause scars upon the valves of many of the pelecypoda; in the dimyarians the anterior pair are attached within the umbones as in *Modiola* or *Mytilus* (iii, 51), or nearer the adductor, as in *Astarte* and *Unio*; the posterior pair are often close to the adductor so that their scars are not separated from it. The *Unionidæ* have two additional retractors of the foot attached laterally behind the anterior adductor (iii, 52); in *Leda*, *Solenella*, and a few others, this lateral attachment forms a line extending from the anterior adductor backwards into the umbonal region of the shell.

At a certain distance within, and parallel with the margin of the shell, is an impression caused by the muscular mantle-margin, and termed the *pallial line* (iii, 31, 32); it connects the scars of the adductors. In the monomyaries it is broken up into an irregular chain of spots. The presence of a *sinus* (iii, 31) in

this line indicates that the animal possesses retractile siphons. The depth of the sinus does not, however, indicate the extent of the contractibility of the siphons, but simply their retractile movements; the very contractile siphons of *Mya* being much longer, and those of certain *Tellinidæ* three or four times the length of the shell. The small siphons of *Sphærium* and *Dreissena* cause no inflection or sinus of the pallial line. When the siphonal sinus exists, its form is characteristic of genera and species.

In *Lucina* and other bivalves there are furrowed impressions caused by the viscera; the absence of polish and outline will distinguish these from muscular scars.

Occasionally the foot muscles are attached to prominent apophyses proceeding from the beak cavity; of this nature are the prominent falciform processes or "teeth" of *Pholas* and *Teredo*. In *Cucullæa* the posterior adductor attachment is bounded by a carina or ridge.

It is by the forcible contraction of the adductors that the so-called swimming of *Pecten* and *Lima* is accomplished. The motion is really a series of rapid dartings, uncertain in direction. Dr. Fischer remarks that, on account of the peculiar form of the valves of *Jouanettia*, the hinge-line being short and the shells gaping apart anteriorly and posteriorly, the contraction of the anterior adductors must increase the posterior gap and *vice versa*, the action of the two pairs thus becoming measurably antagonistic. A similar effect is produced in *Zirphæa*, and indeed in all the numerous species which are termed gapers.

Dr. Lockwood has placed on record* the fact that *Modiola plicatula* when placed in an uncongenial situation, can use its foot, in escaping, with as much facility and in same manner as a gastropod; not only traversing a part of the bottom of his aquarium, but actually gliding up its perpendicular wall to a distance of six inches. Dr. Aug. A. Gould observed *Mytilus edulis* (iii, 40), climb the side of a glass jar by the aid of its foot and byssus, thus accomplishing three inches in a single night. To do this, the animal first stretched out its finger-like foot to its greatest extent, and attached a fibre to the glass, and then withdrew its body within the shell as much as possible, by which the whole was raised about three-fourths of an inch. Numerous fibres were then fixed in a radiating manner until sufficiently secure, and then the whole of the pencil of radiating fibres forming the preceding attachment was thrown off in a mass, at the foot, the ends being still held together by a sort of knot.

* Am. Naturalist, iv, 331.

Dr. Lockwood, in the paper reported above, has witnessed a similar movement by this species.

NERVOUS SYSTEM.

(*Plate V.*) This consists of a group of symmetrical ganglia surrounding the œsophagus, communicating by commissures and sending forth nerves to the various organs. This nervous collar may be considered the representative of the brain of vertebrates. It may be doubted whether the movements of the animal are governed by will to any great extent, most of them appearing to be the reflection of external stimulants, or automatic. The ganglia and the nerves to which they give rise are specialized as follows: 1, cerebral ganglia; 2, the asymmetrical ventral ganglia, branchial, and visceral; 3, the symmetrical or paired pedal ganglia; 4, one or several pairs of small ganglia, called stomatogastric, and connected with the pharynx and œsophagus.

The development of these several ganglia agrees with that of the organs which they serve, and of course where an organ is suppressed, as the foot in the attached oyster, the corresponding ganglia are also undeveloped. Difference in the form of the animals influences also the distribution of the nervous centres, and is mainly shown in the length of the commissure or connectives, which in some cases are very long, in others again, quite short.

The nerves of feeling or sensation are very widely diffused throughout the body. The nerves by which motion is produced are quite distinct from these, yet accompany them so closely as to appear like parts of the same cords.

Cephalopoda (v, 65, 66). The Nervous System is mainly identical with that of the gastropods, yet the relatively high position of the class is shown by the greater concentration of its elements: in the *Octopus* the cerebral volume is considerable. The cranial cartilage contains a pellucid fluid comparable to the cerebro-spinal liquid of the vertebrates. There are the three typical pairs of ganglia, the cerebral, pedal and visceral, surrounding the gullet and connected by commissures; whilst the nerves which supply the buccal mass, the alimentary canal, the heart, the branchiæ and the mantle develop additional local ganglia.*

* The change of color of cephalopods by the chromatophores (iv, 60, 61) is a case of mimicry, but depends on the pallial nerves; their section paralyzes the dilator muscles of the chromatophores and renders the animal pale; irritation darkens its colors by expansion of the same; intense light paralyzes them also temporarily.

The nervous string in each arm of the cephalopods is a centre for reflex movements, in the same manner as the spinal marrow in the vertebrata, and these movements show the character of protection and defense, like the movements of a decapitated frog.—FREDERICQ, *Archiv. Zool. Exp.*, vii, 535, *Physiology of Octopus vulgaris*.

The dibranchiates have the principal ganglia so closely connected that the commissures are not readily perceived. The optic nerves are well developed. The superior and inferior buccal ganglia have each united in one mass, and the two are united by commissures around the œsophagus. The large nerves of the arms, and those of the funnel or siphon, proceed from the pedal ganglia, which are placed on the posterior side of the gullet; with them are connected also the auditory nerves. From the parieto-splanchnic or visceral ganglia proceed nerves along the shell-muscles to the anterior wall of the mantle, where they enter the large *ganglia stellata*; these are connected by commissures, and send strong cords to the fins. Branches of the parieto-splanchnic ganglia, following the vena-cava, supply the breathing and reproductive organs. A recurrent nerve from the inferior buccal ganglion follows the œsophagus, ending in a ganglion upon the stomach.

A modification of this plan is found in the Nautili. Here a thick transverse cord situated in front of the œsophagus represents the cerebral ganglia; from its outer angles the optic and olfactory nerves proceed, from its anterior edge those of the buccal mass. The pedal ganglia placed close to the cerebral ganglia, are united by a slender commissure; from them are supplied all the nerves of the foot or arms, of the funnel and of the ears. The parieto-splanchnic ganglia, lengthened into a thick cord, united at each end with the cerebral ganglia, form the œsophageal ring. Two large ganglia are found, one on either side of the stomach.

Gastropoda (v, 64, 67). The typical arrangement of the nervous system throughout the mollusca being the same, the differences of which we have occasion to speak are simply modifications thereof. The œsophageal ring consists essentially of three pairs of ganglia and a double commissure on each side, and in the more highly organized prosobranchiates these ganglia are approximated and the commissures shortened until the cerebral mass resembles that of the cephalopods, where the ganglia can be distinguished only by the origin of some of the nerves. In species having a simple mouth, the œsophageal ring surrounds the œsophagus immediately behind the oral mass, but in those having a proboscis or snout, it is situated so far back as to remain at rest whilst the proboscis is protruded or retracted.

The cerebral ganglia are placed above or at the sides of the œsophagus, and from them proceed the nerves to the eyes, tentacles, lips and mouth; the pedal ganglia are under the œsophagus, and from them the acoustic and pedal nerves arise; the visceral ganglia are mostly at the under side, somewhat above the pedal ganglia, and here the nerves supplying the mantle, branchiæ, viscera, heart and columellar muscle take

their origin. Almost all of the nerve-cords arising from these three ganglionic pairs may also develop ganglionic enlargements whence numerous nerves in their turn originate. Such is the general plan of the nervous system in prosobranchiates, differing but little from that of the lamellibranchiates or bivalve mollusca.

The most important modifications of this arrangement are found in *Haliotis*, *Fissurella* and *Chiton*. In *Haliotis* the cerebral ganglia are dispersed, not very distinct, but united by a large commissural loop, whence proceed the nerves of the cephalic tissues and organs. The subœsophageal mass furnishes on either side a very large trunk consisting of two superposed nerves: the pallial and pedal, the latter being united by numerous transverse commissures. The commissures of the visceral ganglia are crossed.

According to the observations of von Jhering the pedal ganglia of *Fissurella* are elongated and united by a series of transverse commissures.

The nervous system of *Chiton* (v, 68) shows a simple loop passing over the œsophageal bulb, and united below by a commissure. These mollusks have neither eyes nor tentacles and their mouth is reduced to a simple orifice, consequently the cerebral ganglia are atrophied. The pedal nerves are united by transverse commissures, as in *Haliotis* and *Fissurella* and in the annelids.

In the opisthobranchiates, the ganglia are closely joined, yet distinguishable. The cerebral ganglia are placed above and in front, the visceral below and in the rear, the pedal without; the two latter connected from side to side by commissural loops. From the cerebral ganglia arise olfactory nerves, which develop a large special ganglion in their course. In *Aplysia* and *Bulla* there is a very large genito-branchial ganglion, distant from the subœsophageal ring, with which it is united by a double commissure. In *Tethys* the ganglia are fused into a single body, furnished with a commissure forming a nearly complete circle.

In the pulmonifera or snails (v, 67), the cerebral ganglia are distant in *Limax*, *Vaginula* and *Oncidium*, but join, without commissure in *Glandina*, and *Testacella*. Two commissures proceed from each of these ganglia, the first joining the pedal the second the most anterior of the visceral ganglia of its side. Three additional visceral ganglia, with the two pedal ganglia form a subœsophageal ring, united by commissures as in *Limnæa* or *Zonites*, or close without connectives as in *Glandina* and *Testacella*. Through the midst of the circle passes a branch of the aorta. It will be seen that the visceral ganglia are five in number; their disposition is usually two on the right and three on the left side in snails having dextral shells and *vice versa* in those having sinistral shells. These ganglia innervate the

mantle, lungs, genital glands and viscera. In *Limax*, *Arion* and *Oncidium* they are placed below and more or less mask the pedal ganglia. The stomato-gastric ganglia are small and usually united by a transverse commissure (absent in *Testacella* and *Glandina*); they furnish nerves to the œsophagus, salivary glands and lingual sheath.

Pteropoda. The nervous system is analogous to that of the gastropods, the thecosomata (*Hyalea*, *Cleodora*, etc.) having affinities with opisthobranchiata; the gymnosomata (naked species) with the pulmonifera.

Scaphopoda. In this small group the nervous system resembles that of the lamellibranchiata. There are four much dispersed ganglionic centres: the buccal, pedal, anal, and stomato-gastric.

Pelecypoda (v, 69). The cerebral ganglia of the bivalve mollusks are, as might be expected, small; they are united by a loop or commissure varying much in length, being long in *Anodonta*, for instance, and so short in *Macra* that the two ganglia may be said to touch. They furnish nerves to the mouth, labial palpi and anterior portions of the mantle. Commissures unite the cerebral and pedal ganglia. These connectives are long in those species like *Mya* and *Modiola*, in which the foot is distant from the mouth; short in those in which the two organs are proximate, as in *Teredo*; atrophied in those in which the foot is rudimentary, as in *Pecten* and *Ostrea*. The pedal ganglia are two in number but joined closely, or in *Anodonta*, soldered into a single mass.

The commissures uniting the cerebral and branchial ganglia are extremely long. The latter, two in number, are situated in contact with the posterior adductor muscle. In *Ostrea*, *Pecten*, *Avicula* and *Mytilus* they are united by a short connective, in *Anodonta*, *Macra* and *Mya* they are contiguous. In *Teredo*, which has relatively very large branchiæ, there is one on each side of an accessory branchial ganglion. These ganglia furnish not only two great trunks proceeding to the branchiæ, but also the nerves of the posterior adductor muscle, of the siphons, heart, rectum, etc. A large number of small ganglionic swellings occur in the course of these nerves.

The splanchnic nerves proceed from the pedal or branchial ganglia, and not from special ganglia as in the encephala.

Phosphorescence. Pliny appears to have been the first naturalist who noticed and recorded the fact that the *Pholas*, a lamellibranch or bivalve mollusk, emits a phosphorescent light. This faculty is shared by a number of pelagic gastropods, colonies of which illuminate at night large portions of the surface of the ocean, so that sometimes a ship appears to pass through a sea of fire. The *Pholas* retains its luminosity after it has been cut into fragments, and even after it has been dried, it will

recover this faculty, according to Réaumur, upon being again moistened.

Phyllirhoë bucephala, a pelagic mollusk inhabiting the Mediterranean, exhibits this quality in a remarkable degree. It suffices to plunge it into fresh water to excite its luminosity, and the addition of a drop of ammonia will cause its entire surface to become resplendent for some time with a lively, bluish light.

Panceri has shown that the phosphorescence of *Phyllirhoë* proceeds from special cellules provided with a golden yellow pigment, and analogous to the chromatophores of cephalopods. These *Cellules of Müller* are in intimate relation with small ganglionic swellings of the peripheric nerves, and it has been advanced as probable that the phosphorescent emission is excited by the nervous system.

ORGANS OF SENSE.

Touch. Cephalopoda. This is, of course, the most widely diffused of the senses in the mollusca, every portion of the body being extremely sensible of contact with external objects, but in the *Cephalopoda* the arms may be considered as specialized tactile organs; the *Octopus*, for instance, using its dorsal pair of arms in like manner with the horns of the snail or insects in exploring neighboring objects.

Gastropoda. The principal tactile organs are the tentacles (vi, 72), and edge of the mantle, which is frequently fringed (iii, 45); but there are in addition, in certain prosobranchiates lobular productions of the head near the tentacles, which appear to have a similar function (plate 3).

In the prosobranchiates, the tentacles, always two in number, are solid structures, not invaginate and capable of retraction within the head as are those of the pulmonates; they arise from the front dorsal part of the head and in the probosciferous species are situated at the base of it. The tentacles usually bear the eyes upon stalks which are connate with or branch out from them. The position of the eyes varies in different genera; thus they are found near the bases of the tentacles in *Littorina*, *Dolium* (lxii, 21), or near the middle, as in *Murex*, *Fusus*, *Cassis*, *Mitra*, etc., or even at the end, as in *Terebra*. In *Strombus* the robust eye-stalk originates about the middle of the filiform tentacle (lix, 56). In many holostomates, as *Trochus*, *Nerita* (lxxviii, 57), *Ampullaria*, *Paludina*, etc., the *ommatophores* are entirely separate from the tentacles.

The tentacles are sometimes delicately hairy, and these hairs are evidently tactile also. In the same category of tactile organs must be included the lobes, filiform processes, etc., of the mantle-margin, as well as the processes which beset the mantle lobes of

Cypræa, which lobes are thrown over the back of the shell so as nearly to cover it (lxi, 99). The anterior lobes of the foot existing in many mollusks, as in Buccinum and Harpa for example, may also be regarded as tactile in function.

In the nudibranchiates, besides the various appendages or prolongations of the mantle-border, there are dorsal tentacles (*rhinophores*, vi, 79), situated near the head, and certainly organs of touch.

The Pulmonata or snails are provided with very sensitive tentacles (vi, 72), those of the terrestrial species being invaginate and combining in addition the organs of vision and possibly of smell; while the aquatic species, Physa, etc., have the eye usually separated from the tentacle. Glandina, which is one of the few carnivorous Pulmonata, has remarkably developed labial palpi, resembling enormous moustaches (vi, 72). These palpi, says Fischer, are in ceaseless movement whilst the animal is crawling; and when it approaches another mollusk (Bulimulus or Helix), these organs are applied first to the shell, then to the body of the victim, which is soon drawn, in part, across the extremely dilated mouth of the Glandina. A very large nerve proceeding from the cerebral ganglions is distributed through the labial palpi, the sensibility of which must be extremely delicate.

Pelecypoda. The fringed border of the mantle is very quickly retracted wherever touched. In the Pectens and Limas, which swim rapidly, these fringes are greatly developed. In Unio and Anodonta they are so sensitive as to perceive the slightest movement of the water in which they exist. The extremity of the foot, in the Unionidæ is also very impressionable (Baudon).

Organs of Sight. Cephalopoda (vi, 70, 71). The two sessile eyes are lodged in orbital cavities on either side of the head, in the dibranchiates; in the tetrabranchiates they are elevated upon peduncles. In the former case the cephalic cartilage, as we have already seen, partly encloses them, whilst in some instances special orbital cartilages are also present; the enclosure is completed by a fibrous capsule continuous with the cephalic cartilage, which becomes transparent over the eye and is likened to the cornea or even to the eyelid in vertebrates. This transparent capsule presents several modifications; it may be entire or with a small perforation as in the Octopods, in Sepia, Loligo and other genera, constituting the division *Myopsidæ* of d'Orbigny; or it may have a wide opening, for the projection of the crystalline lens, as in Ommastrephes, Loliopsis, etc.—the *Oigopsidæ* of d'Orbigny: it is entirely wanting in Nautilus.

We find in the dibranchiates a large portion of the eye-chamber occupied by the optic ganglion, by ocular muscles and by a white glandular substance. The silvery *tapetum* lines but does not adhere to the ocular capsule; its two layers pass into one

another at the edges of its free prolongation, which forms the *iris*, and between these two layers occur longitudinal muscular fibres. A layer of cartilage underlying the tapetum, forms the *inner ocular capsule*, which extends externally as far as the iris, and is penetrated on its inner side by the fibres of the optic nerve. The *ciliary body* is formed of connective tissue with muscular fibres and is placed, as a thick rim, upon the free edge of the inner capsule. The *lens* is composed of layers of structureless membrane, which are cuticular productions of the ciliary body; it is almost cylindrically elongated in the direction of the axis of the eye. The vitreous humor is a transparent fluid. The *retina*, lining the inner capsule, has an outer and an inner stratum, separated by a pigment layer. The inner stratum is composed of prismatic or cylindrical rods, the inner ends of which, turned towards the ocular cavity, are covered by a membrane; the outer stratum is filled with the plexus of the optic nerve fibres and with ganglionic cells, connected by tissue; thus the nerve terminations must penetrate the pigment lying between the two strata of the retina in order to reach the rods in the inner stratum.

The pedunculated eye of the Nautilus is much simplified in its structure, having neither cornea, lens nor vitreous humor. The creeping habits of the animal, the abundant protection afforded by its external shell, its want of offensive armor upon the tentacles are here found correlative with a degradation of the visual organ.

A great difference in the size of the eyes in the pelagic and littoral genera accompanies the difference of habit. The littoral Octopus, always existing where the light of the sun penetrates with more or less power, has small eyes, whilst they are enormous in those genera which inhabit the high seas, penetrating to great depths, and which are evidently nocturnal in their habits. So also we find the situation of the eyes to differ according to the habits of the cephalopods: thus the shore species, especially the creepers, have their eyes placed laterally on the back of the head, that they may look above and around, but not below them, whilst the swimmers on the contrary have their large eyes placed directly on the sides of the head to give them equal visual powers in all directions. The eyes in the octopods are fixed, without movement, whilst in the decapods they are free and capable of movement; in the former the skin is susceptible of contraction, so as to cover the eye entirely, fulfilling the functions of an eyelid; whilst in the latter the littoral species are furnished with this protection, but the pelagic ones are without it.

Gastropoda. We have already seen that the eyes are variously situated upon or branching from the tentacles (*ommatophores*)

in most cases ; in others they are sessile or nearly so, upon the head, and situated behind and outside of the tentacular bases. Tentacles and eyes are both wanting in Chiton.

The eyes are spherical, oval, or conical structures, embedded in the skin of the eye-stalk in such a way that the epithelium of the stalks covers them. Externally they are enveloped by a firm laminated membrane (*sclerotica*) which becomes thinned out anteriorly to a cornea. Internally the sclerotica is covered by a pigment contained in polygonal cells, the *choroidea*, which extends forward to the *cornea*, and since the cornea does not cover the whole of the external side of the eyeball but only its middle, a dark pigment ring is seen at its border, which might be described as an *iris*, but cannot be considered equivalent to the same structure in higher animals. In Strombus this iris-like ring exhibits strikingly brilliant colors, yellow, red and green ; often several colors appear in separate rings behind each other, numerous instances of which are figured by Quoy and Gaimard in the Voyage de l'Astrolabe, and used by them as specific characters. In this eyeball, just behind the cornea, the lens is placed, which is nearly spherical and consists of concentric layers. The posterior part of the eyeball is occupied by the so-called vitreous or glassy body which Keferstein regards as a retina.

The eyes of the land snails or Helices (vi, 72, 73, 74), are placed at the extremity of their tentacles or feelers, and can be retracted entirely within the head by invagination, a process which may be likened to drawing in the finger of a glove (vi, 74). The transparency of the horns of a snail is such that invagination may be readily perceived, by touching them and watching the black eye-bulb descend through the constantly shortening stalk, until concealed under the skin of the head. This contraction takes place in a manner which completely changes the relative positions of the crystalline lens and ocular bulb or special retractor muscle of the former, causing it to descend in advance of the latter, which is, moreover, drawn to one side and partly upset in position in descending. Janthina and most of the pteropods, the large Auriculæ, Natica, Sigaretus, Bullia, Chiton, Lepeta, etc., are blind, and in Doris the eyes are covered with a very thick integument, so that vision must be limited to a vague perception of light. In certain genera and species of pulmonates, or land snails confined in habit to grottoes and caverns the eyes are very imperfect. Even a species of Helix, a genus usually so well provided with vision occurs in the grottoes of Carniola with imperfect organs. Certain gastropods exhibit a character of inferiority in the multiplication and diffusion of their visual organs, which appears to ally them to the lamellibranchiates : for like them, the ocelli of Trochus, Margarita, the

nudibranchs, and *Oncidium* occupy various portions of the surface of the mantle.

The Scaphopoda are structurally degraded; the head is rudimentary and possesses no eyes.

Lamellibranchiata. Some of the mollusca which in the adult state are blind are provided with excellent organs of sight during their more active larval existence. Thus, larval lamellibranchiates have a pair of eyes near the mouth, which are wanting to the adults. However, this loss is compensated by the development of numerous ocelli on the mantle-border. These are particularly apparent in *Pecten* (vi, 75), and *Spondylus*, varying in number on the two sides of the body in the inequivalve species: thus, *Spondylus gæderopus* has sixty ocelli on the right or fixed side, ninety on the left side. Small eyes are developed also upon the tentacles or papillæ sometimes ornamenting the extremity of the siphons, as in *Cardium edule*, the Unionidæ, etc. The structure of these ocelli is similar to that of the eyes in gastropods.

Auditory Organs. The organs of hearing in mollusks consist of a pair of sacks or *otocysts*, containing a liquid in which is suspended one or several calcareous concretions termed *otolites*. The walls of the otocysts have a vibratile, ciliated epithelium causing a constant movement of the liquid which they contain. A special acoustic nerve supplies the organ.

Cephalopoda (vi, 71). In the dibranchiates the auditory sacks are lodged in cavities of the cephalic cartilage: they each contain a single, large, calcareous otolite. In the *Nautilus*, however, these sacks are found attached to the pedal ganglia, and contain numerous otolites. The external ears are hollow, plicated processes on the side of the eyes, communicating through a passage lined by a glandular membrane, with the auditory sacks.

Gastropoda (vi, 77). Souleyet first detected auditory organs in univalves, and Siebold, Krohn, Kölliker, Schmidt, Lacaze-Duthiers and Jhering have so multiplied observations upon this point, that their existence in all prosobranchiates may be considered highly probable.

Two auditory vesicles usually exist, and very generally appear to be sessile upon the pedal ganglia, where they appear as small white points. In the heteropoda, in many nudibranchiata, as shown by Hancock, and in numerous genera of branchio- and pulmo-gastropoda, which have been carefully examined by Lacaze-Duthiers, however, there seems to be no doubt that the auditory nerves arise from the cerebral ganglia, even though the vesicles may be situated close to the pedal ganglia.

Within the vesicles are found, in many univalves a single large, somewhat spherical otolite, whilst in others numerous smaller ones exist, amounting to fifty, to a hundred in some

pulmonates, or even, as in the oriental *Melania* and *Melanopsis*, a large laminated otolite together with small crystalline ones. The auditory nerve divides upon the vesicle into a number of branches; and the vesicles are probably connected with the external world by means of an auditory canal; at least such a canal exists (according to Ad. Schmidt) in *Helix*, and Kölliker discovered it in the cephalopods.

The Pteropoda and Scaphoda are provided with similar hearing organs.

Pelecypoda (vi, 78). There is a single auditory organ wanting however, in the adult stage in those genera which then become fixed; it is found in the neighborhood of the pedal ganglia, or even as in *Sphærium*, joined to them.

Notwithstanding the existence of hearing organs in the lamellibranchs is so definitely ascertained, they appear to be entirely insensible to sound, although the Anodonta is tactilely aware of vibrations of the air.

Olfactory Organs. That the sense of smell is well developed in many mollusks has been experimentally ascertained, but the location of the organ has not been satisfactorily demonstrated. Moquin-Tandon relates that a naturalist, observing an *Arion* (garden-snail) moving in right line towards a pea-pod, from which it was two yards distant, picked up the pod and placed it in his pocket. The animal presently halted, and raised its head and directed its horns towards the now unattainable luxury. The pod was now replaced on the earth in another direction and hid by a stone, but the animal was not at fault and turned again in quest of its food. A new change of position of the morsel determined another itinerary, and finally the *Arion* was allowed to enjoy its well-earned meal. Fischer has witnessed the rapidity with which numbers of *Nassa reticulata* assemble around the putrefied carcass of a fish when thrown into the water. They make towards it immediately, from all quarters. On the English coast *Fusus antiquus* is gathered by means of carrion. Whelks (*Buccinum undatum*) are very troublesome to the lobster-fishers, for they often devour the bait, and at St. Margaret's-at-Cliffe, on the Kentish coast (England), the lobster pots are sometimes drawn up, one after the other baitless, and full of these greedy mollusks (Lovell). Even some lamellibranchs appear, by their partiality for putrefying flesh to possess a sense of odor.

The lamellated tentacles or rhinophores of some of the opisthobranchiate gastropods have been supposed by Hancock and Embleton to be olfactory organs (vi, 79). Their nerve is large and provided with a large ganglionic swelling. They are retractile within a special cavity. In the pulmonata geophila, Moquin-Tandon supposes the bulb-like extremity of the ocular tentacles to possess olfactory functions: he finds that after

amputating the tentacles the animal is no longer able to direct its movements towards savory and odorous morsels as did the Arion mentioned above. Dr. Sochaczewer of Berlin, however, does not believe the olfactory organ in terrestrial mollusca to reside in the tentacles. A *Helix* deprived of its tentacles nevertheless manifested perfectly its repulsion for the odor of turpentine, yet a small rod dipped in the essence was held between the tentacles of another *Helix* without the animal manifesting any sensibility of its vicinity. Dr. Leidy locates the sense of smell in a "blind sac or depression opening below the mouth," the mucus canal or *Sinus of Kleeburg*. In the fresh-water pulmonates, Lacaze-Duthiers locates the olfactory organ in a depression of the external side of the basal enlargement of the tentacles.

The seat of the organ in the prosobranchiates and lamellibranchiates has not been determined.

Kölliker has made the interesting discovery that a pair of pits or papillæ, as the case may be, situated behind or above the eye in the Cephalopoda, are olfactory organs. They are pits above the eyes in the Teuthidæ and Sepiadæ and in some of the octopods, but in Argonauta and Tremoctopus they are developed as papillæ, and in Nautilus are elongated like small tentacles, placed immediately behind the eyes. D'Orbigny has mistaken them for external ears.

Many of the mollusca give forth a perceptible odor, agreeable or otherwise, such as the musky smell of the Eledone squid and of the snail *Hyalina fragrans*. Another snail (*Helix fœtens*) is fetid, several give out an odor of garlic, *Bulimus decollatus* resembling laudanum, and Clausilia and Pupa something like sperm.

Apropos to this subject is the following "Note on the Origin of Ambergris," published by Mr. H. Crosse in *Jour. Conchyl.* (3 ser., iii, 204, 1863):

All the world is acquainted with ambergris, so frequently used as a perfume, either singly or in combination with other substances; but the singular conditions under which it is produced are by no means so well known. It is produced by the cetaceans called cachelots, and is simply a result of digestion, a sort of intestinal calculus, a coprolite. This has been confirmed by numerous observers, including both scientific men and whalers. It is formed into balls of various sizes in the digestive canal and appears with the excrement. It is probably caused by an unhealthy state of the animal, as the quantity differs in different individuals from a few to a hundred kilogrammes, according to whalers, and some animals have none. It is encountered in many parts of the world, floating on the surface of the water, than which it is much lighter. And now for the connection of

this substance with our subject. The Cetaceans consume large quantities of cephalopods as food, and many of these latter when living exhale a strong odor of musk; among these may be especially mentioned *Eledone moschatus*, and the gigantic *Loligo Bouyeri*. Now amidst the ambergris are found portions of the corneous mandibles of cephalopods, which the digestion of the whale has not been able to destroy. The ambergris is then, without the least doubt, the result of the intemperate eating of cephalopods. Some of our readers who appreciate the delicate perfume of ambergris, will scarcely thank us for revealing to them in what a singular laboratory it is really prepared; but we cannot change the reality of things—and such persons can, if it seem good to them, employ for the future perfumes of less prosaic origin.

Gustatory Organs. The tongue and mucous lining of the pharynx of cephalopods have been considered to possess gustatory functions, having a crowd of smooth papillæ which probably serve this purpose. That this sense is possessed by the Gastropoda is evidenced by the care and discrimination with which their food is selected, but its special seat has not been determined, for the marine species. Fischer has discovered, in the helices, two small nerves, coming from special ganglia or distinct swellings of the cerebral ganglia, and which penetrate the pharynx; these he thinks are gustatory. The agnatha (Testacella, Glandina), which feed on living prey, do not appear to possess these special ganglia.

The labial tentacles of the bivalves are considered to be organs for discriminating food, but in what way is unknown. They appear, however, to exercise little selection, and swallow anything that is small enough to enter their mouths, including living animalcules, and even the sharp spicula of sponges. In some instances, however, the oral orifice is well guarded.

RESPIRATION.

The respiratory process consists in the exposure of the blood to the influence of air, or water containing air; during which oxygen is absorbed and carbonic acid liberated. It is a process essential to animal life, and is never entirely suspended, even during hibernation. Those air-breathers that inhabit water are obliged to visit the surface frequently; and stale water is so inimical to the water-breathers, that they soon attempt to escape from the confinement of a glass or basin, unless the water is frequently renewed. In general, fresh water is immediately fatal to marine species, and salt water to those which properly inhabit fresh; but there are some which affect brackish water, and many which endure it to a limited extent. The depth at which shellfish live is probably influenced by the quantity of oxygen which

they require; the most active and energetic races live only in shallow water, or near the surface; those found in very deep water are the lowest in their instincts, and are specially organized for their situation. Some water-breathers require only moist sea air, and a bi-diurnal visit from the tide—like the periwinkle, limpet, and *Kellia*; whilst many air-breathers live entirely in the water or in damp places by the water-side. In fact, the nature of the respiratory process is the same, whether it be aquatic or aerial, and it is essential in each case that the surface of the breathing organ should be preserved moist. The process is more complete in proportion to the extent and minute subdivision of the vessels, in which the circulating fluid is exposed to the revivifying influence.

The respiratory system is of the highest importance in the economy of the Mollusca, and its modifications afford most valuable characters for classification, the *orders* being founded upon it.

This classification may be thus stated:

MOLLUSCA.

Encephala.

(Provided with a head: shell when present, univalve.)

CLASS CEPHALOPODA.

Order Dibranchiata, Owen. Breathing by two gills or branchiæ.

Order Tetrabranchiata, Owen. Branchiæ four.

CLASS GASTROPODA.

Order Nucleobranchiata, Blainv. Respiratory organs forming a nucleus on the posterior part of the back, simple and sometimes not specialized.

Order Prosobranchiata, M. Edw. Branchiæ pectinated or plume-like, situated in advance of the heart (Sea Mollusks with spiral shells). Includes the Cuvierian orders, Pectinibranchiata, Scutibranchiata, Cyclobranchiata, Tubulibranchiata.

Order Pulmonifera, Cuv. Breathing by lungs. (Terrestrial, or aquatic.)

Order Opisthobranchiata, M. Edw. Branchiæ arborescent or fasciculated, exposed on the back and sides of the body near its posterior end. (Sea Slugs, Nudibranchiata). Includes the Cuvierian orders, Tectibranchiata, Inferobranchiata, Nudibranchiata.

Order Aporobranchiata, Blainv. Respiratory organ little more than a *ciliated surface*, either situated at the extremity of the

body and unprotected by a mantle, or included in a branchial chamber with an opening in front.

Acephala.

CLASS PELECYPODA.

Order Lamellibranchiata, Bl. Branchiæ or gills lamelliform, specialized from a portion of the mantle.

MOLLUSCOIDA.

CLASS BRACHIOPODA.

Order Palliobranchiata, Bl. Breathing by the arms, assisted by the mantle.

It will be seen that respiration by means of *branchiæ* or gills is the rule with mollusks, those respiring by *lungs* being confined to a portion only of a single one of the five classes, and not including marine species. A few appear devoid of special respiratory organs, that office being performed by the general envelope of the body.

Cephalopoda. The *gills* form a cylinder in Octopus and Sepia, and in Loligo and other genera they are in the form of a half-cylinder; they are two in number in the naked cephalopods, (vi, 80, 82), as well as those possessing an internal shell; and four, arranged a pair on each side, in the Nautilus; hence the terms dibranchiata and tetrabranchiata, forming the highest divisions of the class Cephalopoda. The water finds access to the gills through the large opening between the free anterior ventral margin of the mantle and the body, and it is expelled from the funnel by a muscular contraction of the wall of the mantle; assisted in some genera by a buttoning arrangement described under the head of Cartilages.

The Octopus in repose respire from twenty to thirty-eight times per minute; in movement, fifty times. The respiration of Sepia is, according to Dr. Fischer's observations made at Arca-chon, much more active, he counted seventy to seventy-two respirations per minute in the adult, one hundred and forty in young individuals, an inch in length.

Gastropoda (vii, 90, 91). The branchiæ in prosobranchiates are small, leaf-like, hollow prolongations of the mantle, placed in rows behind each other, and are usually contained in a pouch on the dorsal side of the animal, forming the respiratory cavity. In some opisthobranchiates the gills are lodged at the sides of the body between the narrow, collar-like mantle and the broad foot; such is the position of the filamentous branchiæ of Patella and the laminated gills of Chiton. In the spiral species the right branchia only is well developed, that on the left side being small

and rudimentary; sometimes, however, as in *Turbo* and *Phasianella*, the two gills are brought close together, so as to appear almost as one. In the non-spiral shells, *Fissurella*, *Parmophorus*, and in *Haliotis*, the gills are symmetrical and both well developed.

The form of the depressed respiratory cavity is triangular, in the hinder angles of which the heart and kidney are placed. At the same place also the rectum enters and passes forwards on its right side. At the left side of the same, but attached to its angles, the gills are placed, with the laminæ free and extending into the cavity simple or double, with their basal position in relation with the heart.

On the floor of the cavity, at the right side, by the rectum, lies the vagina or the ciliated furrow of the seminal passages and between these sexual organs and the rectum there is frequently pushed the tubular, inflated excretory duct of the kidney; above on the rectum sometimes lies the prolonged anal gland with its opening in front of the anus, so that the openings of the anus, anal glands, kidney and sexual organs are arranged close together in the above order from without inwards at the right anterior side of the cavity. The covering of the respiratory cavity between the intestine and branchiæ is embraced by the frequently large mucous gland, and between it and the intestine there is frequently a special color gland (*Purpura*, *Murex*).

The *respiratory cavity* has its external opening on the back of the neck, under the mantle-border, which is here contracted to form a rounded hole. Sometimes the walls of this opening are produced into a canal or siphon (xlix, 14), and this difference is one of much importance, agreeing with important modifications of the shell, and (excepting *Natica*) with difference of food. Thus the siphonostomata, as already stated, have the shell terminating in a notch or canal below, and are carnivorous, whilst the animals with a sessile respiratory opening belong to the holostomata, the shells with rounded apertures, and (with the exception of *Natica*) vegetable feeders. In some of the Murices the canal of the shell is very long, but where the canal is short or the aperture simply notched below it by no means follows that the siphon is short; on the contrary, in *Cassis* and *Dolium* it attains an extraordinary length, and is reflected over the back of the shell, so that the borders of its wall become dorsal (lxii, 21).

Although there is no true siphon in the holostomata or herbivorous prosobranchiates, one of the neck-lappets is sometimes curled over, so as to form an analogous organ, as in *Paludina* and *Ampullaria*. The in-coming and out-going currents in the branchial chamber are separated by a valve-like fringe developed from the neck-lappet. In *Fissurella*, *Haliotis* (and the Scaphopoda) the respired current is still more effectually

isolated, as it escapes by a hole in the shell, at or near its apex ; consequently far removed from the point of ingress. Near this aperture are found the anal, renal and generative orifices. Vibratile cilia on the surface of the branchiæ determine the current of water towards the anus after it has completely bathed the gills.

Pulmonifera. The land snails and a large portion of the fresh-water species possess a lung formed by a folding of the mantle, the interior of the chamber thus constructed being lined with arborescent vessels forming small fossets or alveolæ. The opening of this chamber is relatively large, on the right side of the animal, and dilates and contracts at irregular intervals. The air within the cavity appears to be renewed with sufficient rapidity by the law of diffusion. In *Auricula* the respiratory apparatus is a true lung, but in nearly all the pulmonifera it is as described, and in some mollusks the breathing is performed by an organ of an intermediate nature. In *Ancylus* so equivocal is it that it has been called a branchia, a branchial operculum, and a lung. *Ampullaria*, a fresh-water mollusk, the amphibious seashore genus *Siphonaria*, etc., possess both a pulmonary sack and a branchia, *Littorina*, a branchiferous mollusk, usually inhabits stations where it is out of water a considerable portion of each day. I have known specimens to live for months, but without exhibiting much activity, in the air of Philadelphia—which is rather dry. On the other hand, *Melampus bidentatus*, a pulmoniferous mollusk, inhabiting exclusively the seashores of the Atlantic coast of the United States, seeks situations where at high water it is covered by the sea. Many examples might be cited of this adaptability in mollusks, and of modification in the breathing organ, which modify the sharp distinction formerly supposed to exist between the prosobranchiata and pulmonata. The pulmoniferous *Limnæa* usually visits the surface of the water, from time to time, for the purpose of renewing its supply of air, yet it can pass several days immersed without asphyxiation : indeed a species inhabiting great depths in the Lake of Geneva (*L. abyssicola*) normally supplies its sack with water, instead of air, thus justifying the name pulmonobranchiata, which has been given to the androgynous pulmonata. Terrestrial mollusca will survive an immersion of a day's duration in water, during which their teguments have absorbed more than their own weight of the element.*

The production of heat is very feeble in a number of land snails which have been examined by Spallanzani, Gaspard, Hunter, Becquerel, etc., varying from .13 to 3.90 degrees above that of the surrounding atmosphere. The Helicidæ of temperate

* Fischer, Jour. de Conch., 101, 1861.

and cold climates are subject to a winter hibernation, and whilst in this state the heart ceases to beat, respiration is nearly suspended, and wounds do not cicatrize. The *epiphragm* or egg-skin with which the animal at this time temporarily closes the aperture of its shell is slightly permeable by air; like the shell it is a production of the mantle, and is in some species thin and cartilaginous (American and most European species), in others opaque in consequence of calcareous elements (subtropical). It is only formed by non-operculate pulmonates, and occasionally, when the mouth of the shell has been closely applied to another shell, or to a piece of wood or rock, sufficient protection is thus obtained and the epiphragm is not developed. In case the weather is very severe, the mollusk gradually retires farther within its shell, constructing additional epiphragms at intervals—always thinner than the first one. Cold is not the only cause of hibernation; dryness and want of food also produce it, and Fischer,* by placing a *Bulimus decollatus* alternately upon very dry and humid ground found that it would form and destroy epiphragms at the rate of ten or fifteen per month. Heat causes a summer sleep or æstivation, but in this the animal functions are much less interrupted.

In the nudibranchiate mollusca the respiratory plumes form tufts or rosettes exposed on the back or sides of the animal (viii, 92); or they are protected by a fold of the mantle (inferobranchs and tectibranchs of Cuvier). Finally *Eolis*, *Elysia*, *Pontolimax* appear to have no specialized breathing organ, unless this office is performed by the dorsal papillæ of *Eolis*:—it has been doubted, because the animal appears to survive their loss without inconvenience.

Pteropoda. The respiratory apparatus is branchiate when it exists, but is very diverse in its disposition in the different genera. In *Clio* there is no distinct organ; in *Euribia* it consists of two naked appendages of the anterior part of the body; in *Pneumodermon* of a posterior organ, having some analogy to the branchial rosette of *Doris*; in the thecosomata (*Hyalæa*, etc.), it is large, describing a regular curve, with anterior concavity, and contained in a cavity of the mantle.

In the *Scaphopoda* there are no specialized respiratory organs.

Pelecypoda (viii, 89; xxii, 65). In the bivalve mollusca, or lamellibranchiata, so called from the form of the breathing organs, the branchiæ are double, placed on either side of the body, and enclosed between the mantle-borders and the interior visceral mass, the latter interposed. Behind the branchial cavity are two tubes (*Siphonida*) or merely two orifices (*Asiphonida*) for the introduction or exclusion of the water destined for respiration.

* *Mélanges Conch.*, 35.

The lower orifice or siphon is afferent or branchial, the upper one efferent or anal. Movement of the water is produced by vibratile cilia which carpet the branchiæ, and which act also in directing the food towards the mouth. In the Siphonida the tubes or siphons are sometimes very long, and either closely united as in *Mya arenaria* (iii, 54), or more or less divergent (iii, 53). Most of the free bivalves are siphonated and the length of these organs depends upon the depths to which the various species customarily bury themselves in sand or mud. *Mactra solidissima*, a common mollusk of the Atlantic coasts of the United States, is frequently washed shoreward by the waves, which in retiring leave it exposed. Its active foot quickly buries it beneath the surface of the sand, where it awaits the subsequent overflows, its sole communication with the outer world being a hole in the surface leading to the siphonal openings. The pressure of a foot upon the circumjacent wet, yielding sand, causes the ejection of the water contained within the branchial cavity, through the efferent siphon, whence it arises in a forcible stream, several inches, or even a foot or more, into the air.

Our fresh-water mussels (Unionidæ) habitually bury a part of the shell in the river bed, but expose that portion enclosing the siphons; a single species of the Ohio River (*Marg. dehiscentis*, Say), buries itself beneath the surface, communicating with the water through a hole, like the *Mactra*.*

Non-siphonated bivalves, or those in which the mantle is divided into two lobes, are provided with valvules or folds which render the respiratory irrigation just as complete.

The respiratory currents have no connection with the opening or closing of the valves of the shell; these movements being connected with locomotion, or efforts for the expulsion of irritating substances. If an Anodonta be placed in a vessel of water into which some fine sand is introduced, the particles will be seen entering the incurrent siphon and repelled from the orifice of the excurrent one: but after the animal has had enough of the unpalatable and irritating food it will close its valves, forcing out the water, and with it the sand, through both siphons.

In *Ostrea* and its related genera the two branchial leaves of each side are equal and exactly superposed, whilst in the Unionidæ they are unequal, the interior extending further in front than the exterior one; in *Petricola* the external branchiæ are prolonged posteriorly beyond the line of junction of the four leaves, thus producing a third lateral branchia or a reflected portion of the external branchiæ; in *Corbis* and *Lucina* there exists but a single thickened branchia on each side, composed of a number of superposed leaves joined intimately; in *Tellina*

* Lea, Obs., i, 117.

and *Amphidesma* the branchia is single on each side, yet divided by an oblique crease into two parts, like the opposite pages of an opened book.

CIRCULATION, AQUIFEROUS SYSTEM.

Cephalopoda (vii, 80, 83; viii, 87, 88). The heart (vii, 83), which is placed on the hæmal side of the intestine, receives the blood through contractile vessels connecting it with, and equal in number to the branchiæ; these may be regarded as auricles. The branchiæ are not ciliated, and are generally if not always themselves contractile. The arteries end in an extensively developed capillary system, but the venous channels retain to some extent the character of sinuses. In returning to the heart, the venous blood is gathered into the *vena cava*, a large longitudinal sinus, which is situated on the posterior side of the body close to the anterior wall of the branchial chamber, and divides into a number of branchial vessels corresponding with the number of branchiæ. Each of these vessels traverses a chamber in communication with the mantle-cavity (and which may be considered a *renal organ*), and that portion which comes in contact with the water in the chamber becomes sack-like and glandular. The pericardium and the sacks containing the testes and ovaries, appear to communicate with the pallial cavity either through these chambers or directly.

The blood is a white liquid with a slight tendency to bluish, and contains water 89 per centum, Albumen 3 per centum, Salts and substances incoagulable by heat 7·5 per centum, Fibrine, etc., ·5 per centum. The blood of *Octopus* is blue, saline, but less bitter than sea-water, and amounts to about one-twentieth of the weight of the animal; it contains colorless globules, which agglutinate together when taken out of the body. The blood passes from the arteries to the veins by true capillary vessels, not by lacunæ. The heart beats about thirty-five times a minute.—L. FREDERICQ, *Archives Zool. Exp.*, vii, 535.

Gastropoda (viii, 90, 91). The circulation varies greatly as to complexity, according to the higher or lower organization of the animals. In the prosobranchiates (*ibid.*) the circulation is the most complicated, and yet compared with vertebrates, simple. *Arteries* proceed from the heart to the various organs, where they subdivide and terminate in fine capillary vessels. There are no venous capillaries, and the blood flows freely around the organs in the body. There are valves in the *aorta* and *auricles* of the heart which permit the flow of blood only from the auricle to the aorta. From the body-cavity the blood flows into *veins*, some of which conduct to the branchiæ whilst others pass directly to the *ventricle* of the heart. In some genera the arteries do not all end in capillary vessels, but in a portion of them, and espe-

cially in the anterior part of the body these are replaced by lacunæ, as in heteropods and pulmonates, equivalent to both venous and arterial capillaries.

The ventricle is short, conical, with the aorta at its apex with two valves at its origin; and at its opposite blunt end, the rounded auricle, separated by a constriction and like the aorta with two valves at its origin. Sometimes the auricle is divided, a division lying on either side of the heart and receiving each the blood of one branchia. When there are two auricles they surround the rectum, resembling the lamellibranchs in this arrangement.

The auricle always lies in front of the ventricle in the prosobranchiates (as in the pulmonates and heteropods), and therefore the blood flows from before backwards to the heart, whilst in the opisthobranchiates the reverse is the case; and this difference was deemed of sufficient importance by Milne-Edwards to give names to these two orders of branchiferous gastropods.

In prosobranchiates with spiral shells the heart lies behind and below the apex of the respiratory cavity on the left side of the animal, between the anterior portion of the liver and right border of the kidney; in Chiton and other non-spiral genera it is in the median line of the body. The aorta, which arises from the apex of the ventricle, soon divides into two branches, the *aorta visceralis* which supplies the posterior and coiled portion of the animal, its liver and sexual organs, and the *aorta cephalica* which gives off many branches forming a plexus over the stomach, œsophagus, mantle, etc.

Venous capillaries are wanting, as already observed, and the arteries discharge into the body-spaces surrounding the œsophagus, the stomach, the hepatic lobes, the intestine. The blood in the mollusca is typically uncolored; but sometimes bluish and transparent; it is red in Planorbis. Its globules are rounded and finely granulated. By breaking away the shell of a Helix, the circulation of the blood is faintly visible through the thin skin of the body.

Usually there are two large *venous sinuses*, anterior and posterior, from which venous branches collect the blood into two veins, which finally unite in the branchial artery.

The number of heart-beats per minute varies greatly in different species: the marine species have not been extensively investigated. Alder counted 120 pulsations in Vitrina, whilst 20 to 90 pulsations are registered for several terrestrial and fluviatile pulmonates. As excitement or other unusual conditions, as well as the approach of the hibernating period would largely modify the rapidity of the pulse, the mere statement of comparative figures for various mollusks is scarcely scientifically valuable.

Alder records 60 to 80 pulsations in the nudibranchiates. The heart in embryos beats more rapidly than in adults.

The heart is represented, in the *Scaphopoda* by a pulsatile sanguinary sinus, traversed by the rectum and communicating with a system of *lucunæ*, having no lining walls.

Lamellibranchiates (vii, 84; viii, 89). The blood is usually uncolored or slightly bluish, as in the other classes; in *Arca pexata*, however, it is red—this specimen being commonly called the “bloody clam.” The heart occupies the median line: it has a single ventricle, except in *Arca*, and two auricles. The ventricle is traversed by the rectum, except in *Ostrea*, *Anomia*, and *Teredo*.

Aquiferous System. Cephalopoda. Dorsal *aquiferous pores* are found opening upon the head in *Argonauta* and *Tremoctopus*: they communicate with large internal cavities. In *Ommastrephes* and *Tremoctopus* anal pores, with small cavities, are found on each side of the siphon; in *Onychoteuthis* they are placed in advance of it; in other genera they are wanting. The buccal region in *Histioteuthis* and *Ommastrephes* has four aquiferous pores, and there are six of them in *Onychoteuthis*, in *Sepia* and in *Loligo*: the other genera want them. Finally, there are branchial pores situated near the bases of the tentacular arms and between the third and fourth pairs of sessile arms: in *Sepia*, *Sepiola* and *Rossia* they communicate with the great cavities in which are lodged the tentacles when contracted; in *Loligo* the smaller cavity only suffices to lodge a portion of the tentacula, and in *Histioteuthis*, *Ommastrephes* and *Onychoteuthis* the cavity is still more restricted, and only occupies a part of the head anterior to the eyes: wanting in other genera. These pores are probably lubricative in function.

Gastropoda. The aqueous vascular system of the foot and mantle-border forms an important connection between the venous sinus and the external world. It includes one or more pores on the pedal disk of gastropods and lamellibranchiates with direct communication with the body-cavity, and ramifies through the pedal mass (vii, 85). It has been observed as a single pore in *Murex*, *Dolium*, *Triton*, *Strombus*, *Buccinum*, and many other genera. In *Nerita canrena* Delle Chiaje saw the water spirted from a number of holes in the foot.

The statement of the existence of the remarkable communication of the abdominal sinus with the surrounding water was received with little faith, and the subject attracted as little attention, though immediately after Delle Chiaje's discovery, R. E. Von Bär had fully demonstrated its existence in the lamellibranchs, until finally Agassiz made known his weighty confirmatory and thorough observations. In *Pyrula carica* and *P. canaliculata*, Agassiz observed a pore in the pedal disk, which

is so large that it will admit a goose-quill, and which is divided into many branches throughout the foot, which open, by means of numerous finer branches, into the abdominal cavity. Agassiz injected carmine or indigo solution through this pedal pore, and it filled not only the pedal canal system, but also the body-cavity and, finally, the whole vascular system. Quite similar relations were found by him to exist in the bivalve genus *Mactra* (vii, 86). The water actually mixing with the blood in this manner, Agassiz also showed thereby that the blood was exhaled from the body-cavity, salt crystals also being observed, which were derived from sea-water which had been taken up. It has been known for a long time that univalves when removed from the water allow considerable water to escape from them, which runs out of the foot. Agassiz found numerous blood-corpuscles in this water, and there can, therefore, no longer be any doubt that water passes through the pedal pore into the abdominal or body-cavity, where it is mixed with the blood.

On the other hand, the researches of Mr. Wedl have led him to announce the existence in the mollusca of a completely closed vascular system, with capillary networks in the greater part of the organs. The type of distribution of these is extremely variable, and intimately connected with the structure. It is thus that in the *Murices* the skin of the trunk and of the back is formed of several superposed layers of muscular fibres, crossed in different directions, and that several networks of blood-vessels are likewise superposed in these parts. The vascular networks are superposed in the same manner in the foot of these ctenobranchs. In no part of the skin is there any communication between the veins and the exterior; nor do the veins appear to communicate with the aquiferous vessels. M. Wedl, however, has not been able to determine whether these last open directly into the perivisceral cavity, or whether they are distributed only in the foot.—*Sitzungsb. Akad. Wiss. Wien*, ii, 1868. *Ann. Mag. Nat. Hist.*, 4 ser., iv, 365.

DIGESTIVE ORGANS.

Cephalopoda (ix, 93, 94). The organs of manducation in the *Cephalopoda* include a corneous or calcareous beak resembling that of a parrot reversed; within which is a fleshy tongue armed with teeth. These parts are enveloped in a large muscular *bulb* which supplies the force to the jaws. External to the beak are two lips, themselves surrounded and protected by an extensible *buccal membrane* (iii, 48), situated between the buccal bulb and the bases of the arms. The buccal membrane, wanting to the octopods, is well marked in the decapods. In development it forms a vast funnel, and in repose it covers all the exterior part of the mouth. It is encircled by eight or ten fleshy appendages,

externally marked by as many muscular ridges which correspond to the bands connected with the arms. The buccal membrane doubtless assists in retaining the food of the animal in juxtaposition with the mandibles, and for this purpose the fleshy appendages are provided at their external extremity in the Calamaries and in *Sepioteuthis* with suckers similar to those found on the arms.

The *lips*, of which the external one is thin, always short and with entire border, and the internal, in contact with the beak, thickened, fleshy and papillary or ciliated upon its edge, can be contracted over the beak, so as to cover it entirely, fulfilling functions analogous to the lips in mammalia.

The beak is corneous (ix, 95; xxiii, 2, 3, with a more or less calcareous investment in the tetrabranchiates. It differs from the beak of birds in that the superior mandible instead of covering the inferior, shuts within it. The superior mandible is composed of two distinct parts, the one rostral, more or less arcuated, sharp in front, forming behind a hood separated by an inferior expansion varying in length or breadth according to the genus. The inferior mandible, always larger, has a less sharp rostrum, and is also composed of a rostral portion and an inferior expansion; but with this difference, that the lateral part is elongated on each side and forms a wing, varying in form.

The fleshy *tongue* (ix, 98), is armed above with many transverse rows of recurved, spinous teeth, the arrangement of which differs in the various genera. Ordinarily, as in the dibranchiates, we find the series of teeth to consist each of a central one with three side-teeth on either side of it, and sometimes, as in *Eledone* and *Loligo*, an additional plate on either side; but in *Nautilus* we find a modification in five somewhat quadrangular central teeth of which the middle one has the most pointed end, and on either side two long fangs with a much smaller plate at the base of each—in all thirteen teeth in a series. The central teeth, which are simple in *Sepia* and *Sepiola*, are tricuspid in *Loligo* and denticulated in *Eledone*; whilst the lateral *uncini* are usually claw-like. Fifty rows of teeth may be found on the tongue of the *Sepia*; their continuous growth compensates the loss by abrasion.

Under the tongue is found a fleshy mass covered with papillæ, which is supposed to be the organ of taste; and in *Nautilus* we find similar papillæ on the tongue (behind the teeth), to its entrance into the gullet.

The rounded, sack-like *stomach* which is situated towards the middle or end of the body is connected with the mouth by a long central gullet; and the *intestine*, more or less bent upon itself ends in a medial, ventral *anus*.

One or two pairs of *salivary glands* are present in the dibran-

chiates, but wanting in *Nautilus*. The *liver* is always large; and the two *hepatic ducts* are generally glandular. A large and sometimes spirally-wound *cæcum* is frequently developed from the commencement of the intestine, with which the hepatic ducts communicate. The product of the *salivary glands* is uncolored, limpid and acid, whilst that of the *liver* and *pancreas* is also uncolored and acid, but rarely limpid.

In the tetrabranchiata and the decapoda the *œsophagus* is dilated into a *crop* separated from the stomach by a constriction. The *cæcum* is small and rounded, and the intestine is twice bent upon itself. The four-lobed loosely racemose liver is lodged in the anterior portion of the perivisceral cavity, and is largely developed. From either side of it spring biliary ducts which open in the large *blind-sack*; the pancreas is found at their commencement.

Gastropoda (ix, 96, 97; xiv, 72, 74, 76; xv, 81, 78). The digestive organs are well developed. The mouth, which is sometimes in the lower plane of the head, and sometimes at the end of a proboscis capable of protrusion and retraction (lxii, 21), is encircled by extensible lips; within, it is often armed with one or several *jaws* (xi, 34, 36), and the tongue usually bears on its upper surface numerous transverse rows of teeth, constituting the *lingual ribbon* (x, 11). The *œsophagus* is often beset with appendages and salivary glands, and leads to the stomach; whence the intestine turns forward, passing close to the kidney and heart and into the respiratory cavity, the right side of which it traverses and finally proceeds to the anus. The intestine and often a portion of the stomach is embraced by an enormous liver, filling nearly the whole of the first whorl of the shell, and pouring its secretions into the former (and often into the latter also) by several openings. We will successively examine these various organs more in detail.

The *proboscis* is a production of the skin of the anterior or head portion of the body, bearing the mouth at its end. When it remains permanently protracted it receives the name of *rostrum*, that of proboscis being more properly limited to this organ when provided with muscles by which it can be retracted within the body. The typical proboscis is quite characteristic of the siphonostomated prosobranchiates, or those carnivorous mollusks of which the shell is canaliculate or notched at its lower extremity; whilst those animals provided with a rostrum or snout, or with a simple mouth are members of the usually phytophagous holostomata. In *Dolium*, a remarkable exception, the exceedingly long proboscis accompanies phytophagous habits.

The invagination of the proboscis is effected by means of powerful retractor muscles supplied along its entire length and especially numerous at its base, where the retraction begins. The

protrusion of the proboscis, on the contrary, is effected by pressing forward the blood towards the head, an operation assisted by the contraction of the annular muscles of the fore-part of the body. In *Natica*, according to Troschel, the invagination of the proboscis commences at its extremity (like that of the tentacles of snails) by means of two retractor muscles attached to the oral mass. The same observer describes a muscular disk on the under side of the proboscis, behind the mouth, in *Natica* and *Sigaretus*. This disk possesses suctorial action and probably enables the mollusk to attach itself firmly to the shells of other species when drilling them for the purpose of devouring the soft parts.

The oral mass is usually an oval body formed by invagination of the external skin through the mouth, from the upper posterior end of which proceeds the œsophagus, whilst at the lower posterior end is situated the *lingual sheath*, enclosing the *odontophore*. The wall of the oral cavity is filled mostly with flesh-colored muscles and clothed with an epithelium, which is often covered by a thick cuticula, and furnished with cilia on the roof of the mouth.

The lips form a short hollow cylinder at the commencement of the mouth, made up of longitudinal and annular muscles, the latter preponderating; and sometimes forming a ring-like thickening, which is greatly developed and cleft into lobes in the genus *Conus*, and forms another kind of sucking-disk, by the use of which the animal assists its locomotion—necessarily laborious on account of the weight of its shell. In the terrestrial branchiferous genus *Cyclostoma* the snout possesses a similar disk.

Jaws. The inner surface of the lips is sometimes covered by hard plates, which are evidently of much service in grasping and comminuting food. The jaws are attached by their hinder portions to the labial skin or membrane, from the epithelium of which they are secreted. They are hyaline, without structure, and yellowish. Their front face is detached from the membrane and frequently elevated like a scale, bearing sometimes, as in *Dolium galea*, a rounded free hook. In the prosobranchiates the jaws are a pair, situated on either side, but in some of the pulmonates this pair becomes united above, forming a single, arched, superior jaw (xiii, 58, 60).* These cheek plates or immovable mandibles are found in nearly all the tænioglossata, as well in those provided with a *rostrum* (*Cyclostoma*, *Valvata*, *Rissoa*, *Jeffreysia*, *Crepidula*, *Vermetus*, *Trichotropis*, etc.) as in those with a *haustellum* (*Marsenia*, *Natica*, *Cypræa*, *Cassis*, *Triton*, *Strombus*, etc.) They are apparently wanting in all the rachiglossata (*Murex*, *Fusus*, *Nassa*, etc.). The linear horny plates described in *Buccinum*

* The jaw and lingual ribbon of a large *Helix*, such as *H. albolabris* or *thyroides* may be readily observed by offering tempting food, such as a piece of lettuce or cabbage, to the animal.

undatum by Cuvier and Valenciennes, are probably appendages of the tongue, and used as a handle in perforating the shells on which they prey.

Odontophore. The odontophore or so-called tongue (xi, 22; xv, 83) is attached to the floor of the mouth. It is usually curved in front, and its margins rolled together into a cylinder behind, which is supposed to open as the tongue grows forward bringing its rows of teeth successively into use. It contains two parallel cartilages, which may be more or less confluent, and which are united towards the middle by fibrous and muscular tissue. "The intrinsic muscles of the odontophore are attached at one end to the posterior and under faces of the subradular membrane, some being inserted into its posterior and lateral portions, and others into its anterior extremity, after it has turned over the anterior extremities of the principal cartilages. Certain of the muscular bundles are also attached to the forepart of the odontophoral cartilages themselves. The contraction of these muscles must tend to cause the subradular membrane, and with it the radula, to travel backwards and forwards over the ends of the cartilages in the fashion of a chain-saw, and thus to rasp any body against which the teeth may be applied. When undisturbed, the radula is concave from side to side, and the teeth of the lateral series, being perpendicular to the surface to which they are attached, are inclined inwards to one another. But when the intrinsic muscles come into action, the radula, as it passes over the ends of the cartilages, becomes flattened, and the lateral teeth are consequently erected or divaricated. The extrinsic muscles pass from the odontophore to the lateral walls of the head, and protract or retract the whole apparatus. They may give the protruded extremity of the radula a licking motion, which is quite independent of the chain-saw action due to the intrinsic muscles."—HUXLEY, *Anat. Invert.*, 490.*

The subradular membrane does not terminate behind with the muscular mass of the tongue, but is continued and invaginated into a pouch called the tongue-sheath. The under wall of the oral cavity forms a muscular elevation, which is frequently semi-circular, and above which the œsophagus opens. Troschel has regarded this as an organ of taste, and from its position it may well have that function.

The odontophore, radula or lingual plate, is chitinous, subcorneous, transparent and colorless or yellowish. Its surface is

* Geddes has recently carefully investigated the mechanism of the odontophore in *Loligo*, *Buccinum* and *Patella*. He does not altogether agree with Huxley as to the mode of action of this organ, but thinks its movements depend on those of the cartilages, whilst Huxley regards the cartilages as passive.—*Trans. Zool. Soc. London*, x, 485, 1879, with three plates.

covered by a multitude of siliceous teeth symmetrically arranged in transverse rows. The teeth of the anterior portion of the radula are the most developed but at the same time more worn than those of its posterior portion which have not yet come into use, and the projection of which above the surface is scarcely discernable. These teeth are thus developed behind and are successively taken into use. In the Littorinidæ the lingual plate reaches its maximum development, its length, when uncoiled, being in *Tectarius pagodus* seven times that of the body of the animal. In Patella, Chiton, Cyclostoma, etc., the odontophore is also relatively very long.

For convenience of description the odontophore may be divided into five longitudinal areas, which are crossed by the numerous transverse rows of teeth; these teeth are distinguishable in character in each area (x, 11; xii, 13). The central tooth is termed *median* or *rachidian*, the adjoining area on each side bears the *laterals* or *pleuræ*, and these again are flanked by the *marginals* or *uncini*. Sometimes, however, only three areas are found, when the laterals are suppressed, and a cross series includes only rachidian and uncinial teeth. In Bullidæ again, the rachidian teeth are suppressed and there are simply two bands of uncini, whilst in a few gastropods the tongue is unarmed. A numerical formula has been devised which represents these teeth thus:

In Trochus ($\infty . 5 . 1 . 5 . \infty .$), meaning 1 rachidian, 5 laterals and numerous (∞ being the sign of infinity) uncini. Muricidæ have but three longitudinal areas and the formula for Murex, for example, is 1. 1. 1., signifying one rachidian tooth, with a single marginal on either side.

The following list, compiled by Dr. J. G. Fischer, will give some idea of the number of teeth developed upon the odontophores of several species:

Eolis Drummondi, 16 (Möbius); *Eolis papillosa*, 30 (Möbius); *Buccinum undatum*, 240 (Möbius); *Nassa reticulata*, 267 (Möbius); *Fusus antiquus*, 450 (Möbius); *Subulina octona*, 3025 (Fischer and Crosse); *Littorina littorea*, 3500 (Möbius); *Doris tuberculata*, 6000 (Hancock); *Limnæa jugularis*, 8343 (W. G. Binney); *Oncidiella celtica*, 8384 (Fischer and Crosse); *Bulimus Cantagallanus*, 12,100 (id.); *Helix aspersa*, 14,000 (Thomson); *Zonites euryomphalus*, 17,473 (F. & C.); *Helix pomatia*, 21,000 (Thomson); *Orthalicus longus*, 23,660 (F. & C.); *Limax maximus*, 28,800 (Thomson); *Tritonia Hombergi*, 36,000 (Hancock); *Helix Ghiesbreghti*, 39,596 (F. & C.).

Whilst the number of teeth (as well as their form) in each transverse row is constant in the individuals of a species, the number of the rows is, of course, variable, according to age and the usage which the ribbon has received; and the above figures

are therefore mostly individual counts which may vary somewhat in other specimens of the same species.

Rev. G. Rowe observes that* "this subject has been investigated by several naturalists, with a view to obtaining criteria for a systematic arrangement of Gastropodous Mollusca. Up to the present time, however, their labors have only partially succeeded. The union under one formula of so many creatures widely differing in shells, anatomy and habits, clearly indicates that if the lingual ribbon contains generic characters, they have not yet been ascertained. At the same time it does present differences which may offer collateral evidence in cases difficult of discrimination. It does not help us to discriminate carnivorous from phytophagous animals; but it seems possible to make use of it as a mark between species."

On Extracting and Preserving Odontophores. If the specimens are large enough, the head may be opened from above, exposing the buccal mass, which lies close under the skin; this is easily cut away from the animal, and will be found to contain both jaw (when it exists) and lingual membrane. These can be removed by fine scissors or knives, but in the smaller species the whole buccal mass, or even the entire animal with the shell may be placed in a test tube, immersed in Liquor Potassæ, and allowed to soak from a day to several weeks until everything is dissolved except the shell, the odontophore and a few shreds of muscular fibre. The contents of the tube being poured into a large vessel of clean water, the odontophore will settle to the bottom, whence it must be carefully taken out by means of a dip-tube and thoroughly washed until all alkali is removed. Alcoholic specimens require boiling in the alkaline solution, but fresh material had better be treated cold, unless time presses, when boiling will facilitate the extraction of the odontophore. In this case care must be taken as delicate specimens are likely to be injured by boiling. When the specimens are very delicate, a solution of less than officinal strength is substituted with advantage; this is a matter in which experience is the best teacher.

The odontophore can be preserved (in either alcohol or glycerine), but in mounting as a microscopic object, glycerine-gelatine should be used. Canada balsam ruins the membrane by rendering it too transparent.†

Through Troschel, in 1836, attention was first directed to the various forms of tongue-sculpture as being available in classification, and Lovén and Troschel himself by means of the most exhaustive investigations discovered the extraordinary multi-

* *Intellectual Observer*, v, 67, 1864.

† A. M. Edwards, *Proc. N. Y. Lyc.*, 160; W. G. Binney, *Bull. Mus. Comp. Zool.*, iv, 42.



plicity of form, etc., of the radula. In their systematic labors Troschel and Gray raised the radula to the rank of a character of the first importance, in the molluscan, especially the gastropod system, and they accordingly made many changes, rearrangements, and improvements.

To be sure, the tongue and its delicate teeth have been long since known, but they occupied only a subordinate place in the minds of systematists. With Lebert we might agree that Aristotle meant the teeth upon the radula (*Hist. Anim.* vi, 4.) "habent quædam os et dentes, ut *Limax*, acutos et minutos," and not as Lovén held, the jaws, but we meet with a better account of them for the first time in Swammerdam upon *Paludina*, *Littorina* and *Neritina*.

With many other striking observations upon mollusks we meet with the first description of the radula in Adanson, which with the underlying tongue he regards as a lower jaw. "La mâchoire inférieure," writes Adanson (*Hist. Nat. du Seneg.*, p. 17) in a *Bulimus*, his *B. Kambeul*, "ne consiste que dans le palais inférieur de la bouche, qu'est tapisé d'une membrane coriace, mais extrêmement mince, blanche et transparente, sur laquelle sont distribués longitudinalement sur deux cens rangs environ vingt mille dents semblables à autant de crochets courbés en arrière. Ces crochets sont si petits qu'on a peine à les sentir au toucher, ou ne les distingue parfaitement qu'au microscope."

Poli was one of the first to figure the radulæ of cephalopods, gastropods and *Chiton*; then Savigny in his Zoology of the Description de l'Égypte. Cuvier in his *Memoires* correctly described the radulæ of a number of mollusks, but attached little systematic value to the part. On the other hand, Quoy and Gaimard, and Souleyet in the works describing the collections of their voyages, figured many radulæ, but they were not brought forward with sufficient prominence. In Osler's work on the mode of feeding of mollusks, attention was again more especially directed to the radulæ, and Lebert studied the same more particularly with reference to their microscopic characters. As already observed, the extensive observations of Lovén and Troschel are the most comprehensive in their treatment of the subject of this discussion, though the great work of the latter approaches completion very slowly. We shall hereafter sketch an outline of the classifications which have been wholly or partially based upon modifications of the odontophore.

The tongue, beset with such teeth, is well adapted as an apparatus for filing off or rasping food and drawing it into the mouth. In mollusks which creep up on the glass sides of a vessel in which they are confined, one can easily observe the mechanism of eating. The tongue with the whole oral mass is pushed forward a little beyond the lips, so that one can see the

little teeth spreading out. The tongue rubs off particles of nourishment only in the process of retraction, or tears pieces from leaves for example, and draws them into the oral cavity. In seizing and holding the nourishment, the strong annular lip and the jaws are useful accessories.

As already stated, certain corresponding peculiarities of animals and shells enable us to separate the carnivorous from the phytophagous mollusks; curiously enough, the arrangement of the lingual ribbon does not always indicate this separation, and we accordingly find, in systems of classification based upon this organ, the animal and vegetable feeders rather incongruously mixed.

Besides the mastication of food, the teeth are probably used by the carnivorous species in boring through the shells of other mollusks in order to obtain the flesh. It is still a matter of discussion whether this operation is effected by mechanical or chemical action or by a combination of both; but it is generally supposed that the teeth are the tools by which an excavation through the hard shell of the victim is perforated. Most of the large siphonostomate prosobranchiates obtain food in this manner, as well as the Naticas among the holostomates; and I shall have occasion frequently to refer to the subject hereafter when treating of the individual species. The shells attacked are usually bivalves, which are bored near the beaks where they are thinnest. That instinct is sometimes at fault in these creatures is evidenced by the solid spine of a sea-urchin, which P. P. Carpenter relates, has been bored through by a mollusk.

On every coast the evidence of this work of destruction is abundant, a large portion of the bivalves washed ashore, being perforated near the umbones.

Müller has seen *Cerithia* on the Brazilian coast bored by *Murex Senegalensis*, in consequence of which the animal dies and opens its operculum, when a *Turbinella* comes to share the feast. He has seen a dozen specimens of *Cerithium* at one time with the *Murex* extracting the meat through a boring in the spire and the *Turbinella* at work within the aperture of the shell. When both these are done, a *Pagurus* crab occupies the empty shell, or shares it with a *Crepidula*.*

Möbius† has seen *Venus mercenaria* and *Cypræa Europæa* bored through the shell by *Murex erinaceus*, and the soft parts eaten.

Mr. C. Spence Bate has proposed the following theory of the means by which mollusks make these perforations.

“His observations upon the boring of the *Buccinum* into the shells of other mollusca attributed their power of perforation to

* *Jena Zeit.*, 57, 1871.

† *Zool. Garten*, 371, 1866.

a current of sea-water passing through the buccal apparatus, the lingual ribbon having no part in the operation. The animal takes two days to perforate the shell of *Mytilus edulis*, and performs the work without the least motion of its shell, as must be the case whenever a circular hole is bored by mechanical action. The sea-water itself is probably the solvent used in boring by the mollusca, being charged with free carbonic acid; and is directed by them against the object to be bored through the process of respiration, and ciliary currents. The action of sea-water upon limestone coasts in driving tunnels and excavating caverns in the rock is evidence of this solvent power; and the same theory will probably account for the absorption of the columella in the Purpuridæ as well as other instances of absorption by the animal of portions of its shell."

I think that the above theory, ingenious as it is, will not account for the perfectly round hole, with clean-cut vertical walls made by boring mollusks in the shells of their prey; indeed it is difficult to imagine any solvent as the unassisted agent in making such a perforation; yet, on examining a shell not entirely bored through, the bottom of the hole is perfectly smooth, showing no marks of mechanical rasping.

The œsophagus, as already stated, opens into the upper posterior end of the mouth. In those mollusks furnished with a proboscis, that portion of the œsophagus which traverses it is much narrowed, and when the proboscis is retracted it is bent into a sigmoid or coil. In its entire length it is provided with interior longitudinal folds. Its middle is dilated into a sort of crop in *Voluta*, *Dolium* and some other prosobranchiates. Keferstein has found in *Triton variegatum*, and in *Dolium galea* that the œsophagus, just behind the lingual wall (ix, 96), is dilated below into a longitudinal pouch which is filled up with a gelatinous tough mass, projecting into the interior like a ridge: it consists of a hyaline material, with many spindle-shaped or stellate cells with round nuclei. A similar organ has been detected in species of *Murex*, *Voluta* (xv, 82), *Ancillaria*, etc.

The stomach in its simplest form (xiv, 76), is a dilatation of the digestive tract into which the hepatic ducts open. In *Murex* and *Buccinum* it is rounded and curved so that the origins of the œsophagus and intestine approximate. In many of the species a blind sack has been detected in connection with the stomach. In some there are internal lobes or filaments (as in *Mitra episcopalis*), and in others actual tooth-like bodies for compressing the food (*Telescopium*). In *Bythinia*, *Strombus* and *Pteroceras* the blind sack has been found to contain a firm body, somewhat like the hyaline rod of mussels; it extends some distance into the cavity of the stomach.

The tongue of the Bullidæ being nearly unarmed, an organ

resembling the gizzard of a fowl performs the duty of comminuting the food. It is composed of three calcareous plates (xiv, 73), enormous in relative size in *Scaphander lignarius*, which are strong enough to break the shells of the small mollusks which the animal has swallowed entire. In the *Aplysia*, which is a vegetable feeder, a number of semicartilaginous plates and spines perform the office of a gizzard. Again, in *Cyclostoma*, *Paludina*, *Trochus*, *Strombus*, the stomach contains a free chitinous stylet of analagous function, notwithstanding the presence of teeth upon the lingual ribbon.

The intestine in spiral shells may enter the stomach opposite the entrance of the œsophagus, or, in consequence of the bending of the stomach, it most usually enters not far from the œsophagus; it then bends forwards, terminating in an anus situated not far from the respiratory orifice. In the carnivorous species, *Murex*, *Triton*, etc., the intestine is short and direct or nearly so, but in the phytophaga it is elongated and usually forms one or more convolutions (xv, 81). In the rhipidoglossate gastropods (*Turbo*, *Trochus*, *Haliotis*) the intestine traverses the heart. The intestine may be distinguished into two portions, the small intestine and the rectum, the latter being usually enlarged in diameter, confined to the anal end and straight portion of the tube, and having longitudinal folds of its inner wall. In the female, the vagina is placed alongside the rectum, and in some univalves there are anal glands opening by the anus.

The anus is simply a round opening closing by sphincter muscles, situated in the anterior part of the respiratory cavity; and therefore lying on the right side of the animal when dextral, or on the left side when its shell is sinistral. In certain nudibranchs it is dorsal, and in some of the naked snails, etc., at the posterior extremity.

Salivary Glands. Usually a pair of these lie along the œsophagus (behind the œsophageal ring), and open into it close to its entrance into the oral mass. These glands may be tubular and long, dilated behind as in *Strombus*, or the posterior extremity cork-screwed as in *Voluta* (xv, 82), or they may be short or cylindrical or clavate as in *Pleurotoma*, *Littorina*, *Trochus*, etc. Sometimes, as in *Dolium*, *Cassis* and *Triton*, the elongated glands are in two subdivisions, divided by a deep fissure into a small anterior and a larger posterior portion (ix, 96). The two glands may also unite over the dorsal side of the œsophagus, into a single mass, from which, however, separate ducts proceed on either side. When two pairs of salivary glands exist, as in *Janthina*, the anterior pair open near the buccal orifice.

Souleyet was not able to discover distinct salivary glands in *Turbo*, but its œsophagus is enlarged just behind the mouth, and

this enlarged space is furnished with a number of folds which may be regarded as substitutes.

In *Conus* there is only a single gland (xv, 80), and it is very doubtful whether this is salivary in function; Troschel considers it a poison-gland.

In addition to the salivary glands there is found in *Murex* (not observed in other genera), a gland lying above the œsophagus; it is thick, granular in structure, of liver-brown color, divided into several large lobes and opens into the œsophagus by two ducts. Its purpose is unknown. In *Dolium*, the glands are enormous, each consisting of two enlarged portions, the anterior one compact and secreting the saliva, the posterior much larger, membranous, and the secretion of which is distinctly acid, a property first detected by Troschel, and afterwards observed in this and in several other mollusks by a number of investigators.* Troschel states that if the *Dolium galea* is irritated, it will protract its proboscis as much as a foot, and eject from it a quantity of clear fluid, with a very acid smell, and producing effervescence upon calcareous soil. The liquid has been ascertained to contain several per cent. of free sulphuric acid, and about 4 per cent. of hydrochloric acid.† How the mollusk secretes this acid, and how it protects its own tissues and the epithelial cells of the glands themselves against its action is not at all understood. The acid secretion does not appear to be taken into the stomach, for Troschel found in the stomach of *Dolium* seaweed and calcareous remains, which, when artificially brought into contact with the acid, immediately commenced to dissolve. He thinks the secretion is for defensive purposes, and it has been suggested by others that it assists carnivorous mollusks like the *Murex* in boring into the shells of their victims—usually bivalve mollusca.

The liver is a brownish or greenish gland of extraordinary size, which forms almost the whole of the usually spirally coiled hinder portion of the animal from the stomach back, giving up to the sex-glands but a small space. The form of the liver is, therefore, very much the same as that of the posterior portion of the body itself. It is lobulate, and when removed to water is found to be acinose. The acini at their ends are cleft into many digitiform processes; the ducts from the acini unite, then those of the lobes, with frequently sinus-like dilatations, but ending as two bile ducts, placed one before the other, and which correspond to the largest subdivisions of the liver, and approach and, finally, enter the

* *Researches upon the organs which, in the gasteropods, secrete sulphuric acid.* By Prof. Paolo Panceri, *Jour. de Conch.*, 3d ser., ix, 308, 1869.

† De Luca and Panceri have ascertained the existence of free sulphuric acid in the salivary product of *Murex trunculus* and *M. brandaris*. *Ann. Sc. Nat.*, 87, 1867.

digestive tract at the stomach; if a blind sack is present they enter in front of it.

One may accordingly regard the liver as a much subdivided gland, since it is only at a few places, in respect to minute structure, that its ducts and sinuses may be distinguished from the terminal lobes. The liver consists here, as in all univalve mollusks, of an outer structureless membrane and an internal epithelium of roundish secretive cells, which have a distinct nucleus and yellow concretions, and also contain fat. H. Meckel would distinguish fat and bile cells; according to Leydig, however, there is no such distinction possible. The hepatic lobules are united together by thin membrane, plexuses of finely subdivided blood-vessels surround them, and externally the whole liver is surrounded by a blood sinus.

In the nudibranchiates (xiv, 72), the stomach is remarkably branched, its ramifications even entering the dorsal respiratory papillæ in the Eolids. These ramifications have glandular walls which secrete bile and may therefore be considered a singular sort of liver. Although the intestine is functionally replaced by this anatomical disposition, it still exists in the form of a very short tube opening on the right side of the body. The interpretation of the gastro-hepatic organ of the Eolidians has given rise to much discussion. Quatrefages proposed for the Eolis and Elysia the name of *Phlebenterata*, and supposed that the product of digestion (chyle) was aerated in the gastric ramifications by the direct influence of the surrounding water. In the former he admitted a heart and arteries but no veins, in the latter he supposed both heart and blood-vessels to be wanting (*phlebs*, a vein; *entera*, the intestines). He denied an anus to the digestive tube, and thus gave to the hepatic cæca the offices of both digestion and circulation. The fallacy of all this has been shown by Souleyet, who has demonstrated the existence of heart, veins and anus in the Eolidians. The *kidney* or *renal organ* is single in all gastropods (paired in the Scaphopoda and lamellibranchiates), and placed in the vicinity of the heart. It is represented by the *Bojanus organ* of the bivalves.

The kidney is a large, hollow, glandular mass at the base of the respiratory cavity, close to or sometimes perforated (Triton) by the rectum. It contains a fluid having a whitish or brownish appearance, filled with hard granules, and in which Jacobson first detected the presence of uric acid, ammoniac and salts of lime.

If the kidney is cut open the internal cavity is observed, which is, however, much narrowed by numerous thick, spongy, crimped annular folds or meshes, which clothe it internally. The spongy walls, the surface of which, because of the folds is much increased, are covered with round cells, which excrete the urinary products. At the wall of the cells, at least in the youngest ones, there is

always a distinct nucleus and its contents consist sometimes of a yellowish or greenish fluid, and within are concentrically laminated urinary concretions. By bursting, these secretory cells allow the urinary concretions to escape into the water in the kidney.

Externally, the kidney is spun over by a very thick and strong vascular network of the venous system. This vascular network has several openings into the kidney, through which the urinary products are mingled with the blood; and, consequently, when these are examined microscopically, they are found to contain, besides renal cells and free concretions, a considerable number of blood-corpuscles.

Usually the kidney opens into the base of the respiratory cavity by means of a transverse, slit-like opening, encircled by a strong sphincter muscle (Triton, Dolium, Cassis, Murex, Littorina, Natica, etc.); sometimes, however, it has a gut-like, efferent duct, a ureter, which passes forward between the rectum and sexual canal, opening outwards not far behind the anus (Paludina, Turbo, Voluta, Conus). There are accordingly three efferent canals alongside of each other at the right side of the respiratory cavity, viz., the rectum, ureter, vagina or vas deferens. The ureter is usually a somewhat dilated canal and is not simply a prolongation of the kidney, but is often separated from the latter by a diaphragm perforated by a number of holes which are encircled by muscular fibres. Within, a number of longitudinal folds are to be observed, and it is covered throughout with ciliated epithelium. The ureter is usually filled with water and it is possible that it may have some other significance than a mere efferent duct.

Pteropoda. This little group of pelagic animals are much simpler in organization than the gastropods, and to a certain extent may be comparable to the larval stage of some of the latter. Their entire life being passed in the open sea, far from any shelter save that of floating weed, they are active in habit, swimming by the vigorous flapping of their natatory lobes, and, as might be expected, small and fragile as they are, are carnivorous. Clio and Pneumodermon constitute the section Gymnosomata, in which the head is distinct and the animal is without shell; these are provided with tentacles, the surface garnished with suckers, and well adapted for seizing their microscopic prey. There is also a lingual ribbon, well studded with teeth, and two jaws, each consisting of an agglomeration of corneous spines. But the Pneumodermon possesses an additional and very curious prehensile organ which recalls the tentacular arms of the decapod Cephalopoda; in two long cæca placed at the posterior part of the pharynx are lodged cylinders covered with recurved spinules, and which like the proboscis of certain gastropods, the animal

has the power of protracting and retracting at pleasure. In the Thecosomata, those pteropods having a shell, the head is indistinct and tentacles rudimentary, and the mouth is situated in a cavity formed by the union of the two fins. There are two corneous jaws and a lingual ribbon.

In all pteropods the rest of the digestive apparatus is similar and simple in structure. There is a pair of salivary glands; the membranously walled stomach is encircled by the liver which adheres and opens into it by several orifices; * the short intestine opens by an anus on the right side of the body. The kidney is represented by a contractile sac communicating on the one side with the sinus of the pericardium, and on the other with the exterior. It does not appear to be secretory in function, its principal object being the introduction of water to the pericardium.

Scaphopoda (xiv, 71; iii, 43). The Dentaliidae are animal feeders, devouring foraminifera. They have no specialized head, but the mouth is surrounded by several labial palpi, and at its base are numerous very extensible filaments, covered by vibratile cilia, and terminated by a sucker. There is also a lingual ribbon. The intestine is short, and the rectum traverses the sanguineous pocket which represents the heart. The kidneys are paired, opening on the right and left of the anus.

Pelecypoda or *Lamellibranchiata* (xiv, 75). The digestive organs are much more simplified in the bivalve shell-fish than in the Gastropoda. The *mouth* is at the anterior part of the body between two pairs of *labial palpi* (ix, 100; iii, 50, 52), appearing like accessory branchiae and striated upon one face. These lips are equal in dimension, triangular, and varying much in size in the different genera; in *Tellina* even as large as the branchiae, although they are generally much smaller. Mostly simple in outline, those of the Pectinidae are arborescently lobulated. No apparatus exists in connection with the mouth for the comminution of the food, neither tongue, jaws nor muscular pharynx; salivary glands are also wanting. From the mouth a short oesophagus opens into the stomach, and the long intestine, which is usually much convoluted, is terminated by a rectum opening above the posterior adductor muscle (xxii, 65). Mr. Ryder † finds the intestine in the American oyster, to have but one complete turn upon itself, and in the course of its (dorsal) flexure, to pass almost directly over the mouth, and to be provided with a pair of internal longitudinal folds. Except in *Ostrea*, *Teredo*, etc., the rectum traverses the ventricle of the

* In *Hyalaea* there is a crop and gizzard armed with corneous plates; the liver is not adherent.

† Am. Naturalist, 674, 1880.

heart The liver embraces the stomach and a portion of the intestine, its acini forming numerous lobules which open by orifices into the former, and the anterior portion of the latter. There is usually a blind sac; sometimes, as in *Pholas*, *Tellina*, etc., very long, and extending between the circumvolutions of the intestine. Within this is generally lodged a transparent, cylindrical, cartilaginous body called the crystalline stylet, which is sometimes present, sometimes absent in the same species, from which Siebold infers that its appearance is periodical. It is probably an accessory digestive organ; but appears to be absent in some of the *Monomyaria*. In the *Unionidæ* the stylet is found in the intestine (it is over half an inch long in *U. cariosus*), and the blind sac is not developed. Those *Pelecypoda* having a closed mantle receive through the incurrent siphonal tube such microscopic food as may accompany the water inhaled for breathing; in others the water has free access to the gills; and in both cases the ciliated laminae of these organs arrest floating particles of food and mould them into threads by a viscid secretion of the surface; they are then propelled in the direction of the mouth, which they enter between the palpi. Minute vegetable organisms and animalcules are found in great abundance and variety in the stomachs of bivalve shell-fish.

The renal organs are paired, and have received, after the name of their discoverer, the appellation of *Organs of Bojanus*. They consist of symmetrical glands, at the base of the branchiae, in the dorsal region. The excretory canals of these glands open, in *Mactra*, *Unio*, etc., contiguous to that of the genital organs; in *Arca* and *Pinna* they unite with the oviducts; in the *Pectinidæ* the genital glands pour their products directly into the *Organs of Bojanus*. In the *Unionidæ*, *Cardium*, *Pholas*, etc., Lacaze-Duthiers has found another orifice by which this organ communicates with the pericardium. The organs of Bojanus are brownish or greenish yellow, spongy, and secrete uric acid, with concretions of carbonate of lime.

ORGANS OF SECRETION.

Besides the salivary and urinary organs described in connection with the chapter on the digestive system, there exist in some mollusks special organs, the products of which are sufficiently important in character to require particular description. The first of these is the Ink-gland of the *Cephalopoda*.

The ink-bag or anal gland (ix, 93), (not present in *Nautilus*), is a tough and fibrous sack, the outer coat of which is thin and silvery; the contents are discharged by a duct direct (or, as in most decapods, through the anus) into the mantle opening, and thence diffused in the surrounding water; covering the movements of the animal by the obscurity in which it becomes almost

instantly enveloped. There can be no doubt of the use of this organ in facilitating escape from danger. The ink itself was formerly used by the Chinese in the preparation of sepia or India ink, but this substance is now made from lampblack. The method of preparing sepia practiced on the shores of the Mediterranean, is to carefully extract the ink-bag and dry its contents. Triturated with caustic soda or potash, it is afterwards boiled for half an hour with caustic lye, and finally the liquid is treated with an acid until neutralized. After standing, a precipitate falls, which is collected and dried by a mild heat, and forms the sepia of commerce. So indestructible is the ink, that it is frequently met with preserved with the fossil remains of Belemnites and other extinct genera. The full protection afforded the soft parts by the external shell of the tetrabranchiates accounts for the absence of the ink-bag in that division of the cephalopoda.

An analysis of sepia shows that 78 per centum is composed of the black coloring matter (the Melania of Bizio), and that of the residuum there is 10 per centum carbonate of lime, 7 per centum carbonate of magnesia, and sulphate and chloride of soda 2 per centum.

"Mr. Lloyd states, in his interesting 'Handbook to the Marine Aquarium,' that the ink (which is viscid) does not generally become diffused through the water as writing-ink would be, but is suspended in the water in a kind of compact cloud till it gradually settles down, and is dispersed in flakes. Now I quite think, with Mr. Lloyd, that this being the case, it is difficult to perceive how, according to the generally received opinion, the retreat of the animal is covered by the ejected cloud. It seems to me more likely that this discharge is to divert the attention of a pursuer—a dog-fish for instance—which would for the moment be startled by the sudden appearance of masses of dark color in the water, and in the confusion the cuttle makes his escape."—W. R. HUGHES, in *Nature*, ix, 363, 1874.

Purple Gland (xv, 79). This gland accompanies or is a modification of the mucus-gland. It is only found in a portion of the prosobranchiate gastropods; among them, in both the typical Muricidæ and the Purpuridæ; but a similar gland secretes a violet liquid in *Janthina* and *Aplysia*, and yellow in the Bullidæ. The peculiarity of the fluid secreted by this gland is, that originally colorless or yellowish, a short exposure to sunlight changes it to a brilliant violet or reddish color, at the same time giving off a very penetrating fetid odor.* The cause of this photographic change of color is unknown, but the knowledge of it came to mankind in very early ages, and Tyrian purple was

* It is colored at the moment of its secretion in *Aplysia*.

the most highly prized and most beautiful dye known to the ancients.*

Pliny states that in his time the purple dye was obtained from the Buccinum and the Purpura. The mollusk now known as *Murex trunculus* is generally supposed to have been that principally used by the ancients in obtaining the Tyrian purple. It is related that the discovery of the dye is due to the dog of a Tyrian nymph, which crushing some of these shells in its teeth, its mouth became stained with purple. It is possible that the fragile *Ianthina* may have been thus crushed, but the shells of the *Muricidæ* would resist the dog's teeth. To be exact, this event occurred 1500 B. C. The color was so beautiful that the fair nymph expressed to her lover, Hercules, her desire to have a robe of similar hue. Hercules, of course, gratified her. It is evident that the product of two different species was mixed in order to produce the finest color, as Pliny gives the proportion of 200 pounds of juice of "Buccinum," and 111 pounds of that of "Pelagia" as suitable for obtaining a beautiful amethyst color, sufficient for 50 pounds of wool. The extent of the Tyrian industry is visible in numerous holes in the rocks, two to three feet deep, containing the breccia of shells anciently crushed in them for the extraction of the dye. The arms of the city as preserved on its medals was the purpura shell, and in the time of Strabo the multiplicity of dye-works unpleasantly affected the air of the vicinity. The Romans used various species in great quantity for dyeing purposes, and the remains of Murices form vast heaps; indeed in one case, at Tarento, the mass is so large as to have received the name of "Monte Testaceo."

The color was prepared by pounding up small specimens, or by breaking the shells of larger ones and extracting the purple gland. This fluid was mixed with five or six times its weight of water, with twenty ounces of soda to every hundred pounds. Placed in lead or tin vessels the mixture was exposed to the sun for several days, until the hue desired was obtained, when the wool was simply plunged into it and allowed to remain for a few hours. Under Augustus the dyed wool brought as much as \$200 per pound.

The Indians of the new world also understood the art of purple dyeing from shell-fish, and it is probable that all ancient peoples inhabiting sea-shores have become accidentally acquainted with this property, common to so many mollusks, at a very early

* See Lacaze-Duthiers' (*Ann. Sc. Nat.*, xii, 5, 1859) exhaustive "Mémoire sur la Pourpre," an exceedingly interesting paper, illustrated by specimens of the color resulting from various applications of the dyes obtained from Murices, Purpuras, etc. See also *Smithsonian Report*, 1863; *Lovell's Edible Mollusks*, p. 124; *Grimaud de Caux, Rev. et Mag. Zool.*, 34, 1856.

date. The Roman law prohibiting the use of purple garments to any but the imperial family, was a deathblow to this industry, which thenceforth rapidly declined. During the middle ages the very existence of such a dye was considered fabulous; but with the revival of the arts and civilization its properties were rediscovered, and for awhile successfully utilized. Chemistry has now supplied us with even more brilliant colors, whilst saving much of the cost of procuring material.

An anal gland accompanies the purple gland in *Murex* and *Purpura* and has not been discovered in other mollusks. It lies on the left side of the rectum and consists of a central canal with lateral branches having a dendritic appearance. It opens on the edge of the anus, and by pressure its brownish contents may be made to issue. The function of this, as well as of the purple gland is unknown.

The *Mucus-Gland* lies in the middle portion of the cover of the respiratory cavity in most prosobranchiates; its tough secretion is discharged through the respiratory opening in extraordinary quantity, especially when the animal is handled.

The glands of the mantle-border of *Oncidiella* are remarkable for their size and the regularity of their position. They all open at the summit of little cutaneous eminences, and they secrete an abundant whitish liquid.

Mucous glands are largely developed in the *pulmonata geophila* or terrestrial pulmonates. There exist in *Limax*, *Helix*, etc., a series of unicellular glandules the contents of which are poured into a large canal which opens on the anterior part of the body between the head and foot. This organ was discovered by Kleeburg, after whom it is named. Its functions have been variously interpreted, and Leidy has thought *Kleeburg's Sinus* an olfactory cavity.

In *Arion*, *Helicarion*, *Parmarion*, *Nanina*, etc., there is a mucous gland opening by an orifice (*mucous pore*) at the dorsal posterior extremity of the foot: its product is very abundant.

Many gastropods and bivalves secrete a glutinous thread, strong enough to support the weight of their body. Thus the young of certain limaces descend from one branch to another, suspended by a filament adhering to their tail. *Chondropoma dentatum* produces a filament which passes between the operculum and the wall of the shell, by which the animal suspends itself to branches or leaves. Numerous filaments fix in like manner the *Cerithidea* to brackish-water plants. The fresh-water univalves *Physa*, *Limnæa*, *Planorbis*, *Neritina* and *Bithynia*, and the bivalve genus *Sphærium*, suspend themselves in the water in like manner; *Rissoa*, *Odostomia*, *Eulima*, *Cerithium* are examples of marine mollusks possessing a like faculty. *Litiopa*, a small gastropod, lives abundantly in the floating fuci and

sargassums, suspended by one or several filaments. If these cords be broken, the mollusk emits an air-bubble enveloped by a glutinous substance which rises to the surface of the water, carrying with it the end of a new filament: upon coming in contact with the fucus a new attachment is formed.

The *Ianthina* constructs a floating apparatus or raft (xvii, 99), attached to its foot and comprised of a quantity of airy vesicles. Lacaze-Duthiers states that upon detaching the float the animal sinks; but that the groove of the foot imprisons some air-bubbles under a glutinous envelope, by the aid of which it again seeks and maintains itself upon the surface of the water until a new raft is developed.

Many of the lamellibranchiates secrete a byssus. Its gland is situated in a groove towards the base of the foot, on its ventral surface. It produces a number of elastic, adhesive filaments by the aid of which the animal attaches itself to submarine bodies (iii, 41). In *Tridacna*, *Avicula* and *Arca* the filaments cohere, forming a homogeneous mass; in *Pinna* the fibres are distinct, fine, numerous, silky, and capable of being woven, so that gloves have been made from this material. In *Mytilus* the filaments are frequently separated at the attached end so as to occupy several points of anchorage (iii, 40).

Many embryonic Unionidæ are known to possess a byssus, and a few adult species also have it; in *Unio acutissimus* it is over an inch in length (Lea). By means of its byssus a bivalve mollusk is able to ascend perpendicular surfaces. It abandons at will the various threads it has woven, and also breaks those which impede its movements. The activity of the byssal gland of *Pecten varius* is such that Fischer has observed at Arcachon, an individual secrete sixty byssal bundles in eight days, during which time it had elevated itself on the aquarium glass to a height of about two feet—each abandoned byssus being attached about .4 inch below its successor.

The byssal plug of *Anomia* is the calcareous product of a gland replacing the byssal gland; morphologically it is a calcified byssus.

SEXUAL ORGANS.

There is much diversity in the reproductive organs of mollusks, and in some of them the whole history of reproduction is fraught with so much interest that I deem it advisable to devote a few pages to the subject. The reproduction of mollusks is in all cases effected by means of eggs. In a few gastropods the young are hatched and retained for a period within the oviducts of the parent—such ovoviviparous species are *Paludina*, *Cymba*, etc.; the eggs of the acephala also sometimes remain within the parent shell until hatched.

In the Cephalopoda and the prosobranchiate gastropods the sexes are distinct (dioecious), but they are united in the same individual in most of the other mollusks (monœcious). The Cephalopoda and prosobranchiates pair, the monœcious land snails require reciprocal union; the limneids unite in succession, forming floating chains; in the lamellibranchiates the spermatozoa are discharged into the water, whence they are inhaled with the respiratory currents.

Cephalopoda (xvi, 84–87, 90, 92). The sexes are distinct, and in some of the genera at least, the female individual is the largest and readily distinguishable externally.* The reproductive organs are lamellar or branched; their cellular contents are metamorphosed into *ova* or *spermatozoa*, which are attached to the wall of a chamber communicating with the pallial cavity by one or two ducts, which, in the female present glandular enlargements. Upon the walls of the branchial cavity of the female two *nidimental glands* are developed; besides, sometimes accessory glands, within which is secreted a viscid fluid which envelops the ova and aggregates them into various forms, differing according to the genus.

In the male the cases or *spermatophores* (xvi, 92), containing the spermatozoa are furnished by a prostatic gland. These spermatophores, in the dibranchiata are ovate, cylindrical and narrow, consisting of a thin case, ending sometimes in a filament at one end; at the other or thicker end is contained a sack full of spermatozoa, to which is attached an elastic spiral cord, coiled and compressed within the balance of the case. Upon coming in contact with the water these spiral bodies commence moving and finally burst through the thin end of the investing spermatophores dragging with them their sacks of spermatozoa.

In *Nautilus*, Van der Hoeven has ascertained that the structure of the spermatophores is much more simple. In this genus the oviduct arises from a chamber which communicates with that in which the ovary is lodged. A large albumen-gland opens into the latter. So also the *vas deferens*, instead of originating directly from the sack of the testes, communicates with it through an intervening chamber.

The most curious portion of the sexual history of the dibran-

* The sexes in *Sepia officinalis* may be readily externally distinguished. There is in the first place a difference of coloration, the females being unicolorous, whilst the males have zebra-like markings across the marginal fins and the dorsal arms—especially when irritated. But the best means of distinction is in the relative lengths of head with the arms and body; in the males these two dimensions are about equal, but in the females the body is only two thirds the length of the head and arms. The cuttle bone in the female is much wider and more excavated behind.—BERT, *Mem. Linn. Soc. Bordeaux*, v, 118.

chiate Cephalopoda is undoubtedly that which relates to their sexual union, accomplished through the offices of one of the arms of the male, which becomes modified in its structure for this purpose. This arm, very unlike the others in appearance, sometimes becomes detached from the animal during the sexual union, and remains within the mantle of the female for a period, during which it enjoys a separate life. Each genus seems to be characterized, not only by the particular arm, either on the right or left side of the animal which is thus *hectocotylized* but also by differences in its appearance and structure. The third left-side arm of the Argonaut is first developed as a balloon-shaped sack, which finally splits open and reunites its halves upon the dorsal face of the arm which emerges from it, forming a chamber which becomes filled with spermatophores, in a manner not yet understood. Indeed the investigation of this whole subject may be considered as yet in its infancy, and many points remain to be cleared up; thus in some genera no sack for the reception of spermatophores has been found, and the hectocotylized arm appears to perform its office without subsequent detachment from the animal, merely inserting itself within its own mantle to gather spermatophores, which it proceeds to deposit upon the buccal membrane of the female. The detached hectocotyle when first discovered in the mantle of the female was naturally regarded as a parasitic worm; that of Argonauta being termed *Trichocephalus acetabularis* by Chiaje and that of Octopus *Hectocotylus octopodis* by Cuvier. More recently it was supposed to be the entire male animal of the cephalopod.

The specialization of an arm for reproductive purposes in the Cephalopoda is curiously paralleled in the arachnida, as in some species of spiders certain parts of the palpi of the males are transformed for the same purpose into spoon-shaped organs. As to the loss of the hectocotylized arm, which at least occurs usually in some genera, as *four* of them had been discovered in the mantle opening of a single female Octopus, there is no doubt that another arm is developed to take its place, and it is probable that these succeeding arms may be hectocotylized like the first.

In Tremoctopus the third arm on the right side becomes hectocotylized; it is then worm-like in appearance, with two rows of suckers on its ventral surface and an oval appendage at the posterior end. The anterior part of the back is fringed with a double series of branchial filaments (250 on each side). Between the filaments are two rows of brown or violet spots. The suckers (forty on each side) closely resemble, but are much smaller than those of the normal arms. Between the suckers are four or five series of pores, the openings of minute canals passing into the interior. There is an artery and vein on each side, giving branches to the branchial filaments, while a nerve

runs down the centre. The *oval sack* encloses a small but very long convoluted tube, ending in a muscular sack which contains the spermatozoa.

The hectocotyle of the Argonaut is very small, only half an inch, with a filiform appendage in front of about equal length; it has two rows of alternate suckers, forty-five on either side; but no branchiæ.

In Octopus the hectocotylized arm instead of being much shorter than the others, as in Argonauta, becomes much longer. It terminates in an oval plate, marked with numerous transverse ridges and intervening pits, and this is connected by a muscular fold of skin running along the dorsal face of the arm with the webbed base covering a passage through which the spermatophores are probably transmitted to the terminal plate.

It has already been shown that in the male Nautilus the four inner ventral tentacles become united into a so-called *Spadix*; this is now believed to perform in the tetrabranchiates the sexual office.

M. Steenstrup remarks that it is evident this peculiar structure, sometimes of one pair of arms, sometimes of another, sometimes to the right, sometimes to the left, sometimes at the summit, sometimes at the base, etc., must involve many differences in the mode of fixation of the spermatic masses or spermatophores on the females, and (inasmuch as the semen does not seem to be poured upon the eggs by involuntary or mechanical, but by conscious movements) in the manner in which fecundation is effected. This is confirmed by observation. The spermatic masses are in reality fixed on very different places and in very different conditions—namely, in the genera *Sepia*, *Sepioteuthis* and *Loligo* (consequently all those in which he has found the left ventral arm hectocotylized) the spermatic mass is fixed on the internal surface of the buccal membrane of the females, which is specially organized for that purpose; whilst in the other decapoda he has never found the sperms fixed in that place, but on various parts of the mantle or of the interior organs, in *Ommastrephes*, for example, far back in the cavity of the mantle, towards the middle part of the back.

In the "Actes de la Société Linnéenne," of Bordeaux, 1872, M. Lafont states that a *Sepia Filliouxii* deposited its eggs in one of the basins of Arcachon, on the 23d of May, 1870, attaching them to a *Zostera* (xviii, 13–14.) Taking it from the water, he found all around the mouth, attached by the large end, a certain number of little sacs filled with spermatozoa. Replaced in the water, the animal continued to oviposit. In again examining it, at the end of about a half-hour, he saw that the number of sperm-sacks had diminished, not more than a dozen remaining. As soon as again put in the water, a male approached and a

sexual union took place. He immediately examined the female again, and found the mouth surrounded by spermatophores attached to the buccal membrane. After this examination, the animal was permitted to continue ovipositing, which she did for more than two hours. It is evident, says M. Lafont, that these spermatophores serve to fecundate the eggs at the moment when they pass out of the siphon and when the female takes them between her arms. Since that period more than half of the females of *Sepia* and nearly all those of *Loligo* that he has examined, were found to carry a greater or less quantity of spermatophores around their mouth.

Steenstrup has shown (*Ann. Mag. Nat. Hist.*, 2 ser., xx, 1857) that whilst the octopods (which alone are known to lose their copulatory arm) possess in the highest degree the power to reproduce mutilated members; the decapods, on the contrary, are not able to remedy such losses by a new growth; and this is a cogent reason for believing that the process of fecundation is entirely different in the two groups. Steenstrup states that the hectocotylized arms, so far as he can ascertain, present no changes at the season of copulation, that they present the same features in small as in large individuals; and he assumes that when the young male leaves the egg it is already furnished with the hectocotylized arm proper to its species.

Braun has supposed the aptychi to be the shells of the males of Ammonites, instead of opercula; thus he explains why they are so often found at the base of the first chamber of Ammonites. The opinion has more recently been advanced that the aptychi were protective organs of the nidimentary glands of female Ammonites.

M. Ussow observes that the spawning time of *Argonauta* lasts from May to August; of *Loligo*, *Sepiola* and *Ommastrephes*, from March to June; but he has obtained mature ova of *Sepia* in Naples almost all the year round, except in August. —Ussow, "Development of Cephalopoda," *Ann. Mag. N. H.*, 4 ser., xv, 1875.

I have figured a few forms of egg-clusters (xviii, 12–15): unfortunately the eggs of the *Nautilus* are not known, so that our knowledge is confined to the dibranchiates. Of these the most curious is the *Argonaut*, the elegant shelly structure of which originates, as we have seen, from the expanded dorsal arms of the female which cover its sides and form the only attachment of the animal to it. In the unoccupied hollow of the spire are attached the minute clustered eggs (xviii, 15), and its special function appears to be for their protection during development. Each egg is separately enclosed in a rounded shell, which is furnished with a long, thin membrane of attachment. We know but little of the eggs of *Octopus*: Aristotle describes them as

similar to those of *Argonauta*, and attached within shells or similar concave surfaces.

In *Sepia* each egg is enveloped in a large, spindle-formed black capsule, many of which, forming a close mass, are attached to some marine body.

Another form of egg-masses is that in which a number of eggs are contained in a single large capsule (of which many are aggregated into a mass), attached by its pedicel to some submarine object. In *Loligo vulgaris*, for example, each long bag-like capsule contains thirty to forty eggs. The capsule of *Sepioteuthis* is similar, but shorter, and contains fewer eggs.

During the summer of 1876 I resided at Atlantic City, on the New Jersey coast, and then enjoyed frequent opportunities for observing the development of *Loligo punctata*, De Kay (xviii, 12); masses of egg-capsules of this species being thrown upon the beach in considerable quantity throughout the season. Some of these masses, when the embryos had attained considerable growth, had grown to prodigious size and weight, being several times larger than the animal which deposited them. I have seen hundreds of cylindrical cases, each three to four inches long and half an inch in diameter, composing a single, soft, jelly-like mass, which lay quivering on the beach, reflecting from its glistening surface rainbow hues, and filled with almost innumerable, rapidly pulsating embryos; say, at least 250 to each sack. The details of their form and the colored spots of their body were distinctly visible to the naked eye. Each embryo is enclosed in its separate round, transparent egg-case, and during its development the yolk-bag is attached to its mouth, and surrounded by its arms.

Cuthbert Collingwood (*Jour. Linn. Soc.*, xi, 1873), encountered (in 1870), floating upon the surface of the Atlantic Ocean, in lat. 37° N. and long. 28° W., a gelatinous object, somewhat cylindrical in form, about two feet long and four or five inches in diameter, and containing cephalopodous ova arranged in clusters and single rows. The young animals were very active, and in fact were all discharged a short time after the nidus had been secured. It is impossible to ascertain positively at present to which genus this curious form belongs, though evidently the animal is finned and pelagic. The whole oviposit is here united within a single gelatinous covering instead of being aggregated into sausage-shaped masses each filled with embryos as in *Loligo*, or in separate eggs as in *Sepia*. A similar floating mass was obtained by Dr. H. Grenacher, at the Cape Verd Islands, in January, 1872; it was nearly 2.5 feet long by 6 inches in diameter (*Zeit. Wiss. Zool.*, xxiv, 1874).

Quoy and Gaimard (*Ann. Sc. Nat.*, xx, 1830) discovered near the Moluccas, a cylindrical nidimental mass, three feet long and six to eight inches diameter, composed of cephalopodous eggs

placed in double rows on a ribbon, the circumvolutions of which with margins overlapping, formed the cylindrical shape.

Gastropoda. Prosobranchiates, etc. The sexes are distinct in the prosobranchiates; the organs are, however, very simple and so alike in structure, that frequently the sex of the gland can only be determined by microscopical examination. Usually a germ-secreting gland is imbedded in the liver, from which an efferent duct opens at the right side into the mantle-cavity. In most cases the males may be readily distinguished by the large penis, which is placed at the right side of the head behind the eyes. In *Patella*, *Haliotis*, *Hipponyx* and *Trochus* there is no copulatory organ. Their genital gland opens in the neighborhood of the anus. Latreille has proposed the name *Agama* for gastropod mollusks without copulatory organs; the others are distinguished as *Exophallia* by Mörch. The shell in the female is generally more inflated than in the male.

Female Organs (xvi, 89). The ovary discharges into a much looped oviduct, and the latter dilates into a gut-like uterus—the last portion of which on account of its muscular wall may be regarded as a vagina. There is sometimes at the commencement of the uterus, or at its connection with the vagina, a seminal pouch, but other appendicular organs are seldom present.

The last portion of the uterus or even the whole of it, and the vagina lie in the respiratory cavity, to the left by the side of the rectum and nearest to the abdominal wall. The sexual opening is accordingly found to the left of the anus, but usually far behind it. Sometimes the uterus is split through its entire length and its folds formed by the longitudinal and transverse plaits, consequently lie freely exposed in the respiratory cavity. Lacaze-Duthiers has so described it in *Vermetus*.

There is scarcely anything to be said in regard to the eggs of the prosobranchiates, generally. Where their development can be seen, a distinct germinal vesicle and germinative dot are present; but when they leave the ovarium the yolk granules are present in such numbers as to conceal this structure. In the oviduct, or quite above the uterus, the eggs come into contact with the zoöspers, which are occasionally retained at this point in a spermatheca. Further down in the uterus fertilization could no longer be effected as they here become enclosed in a tough albumen, and finally are covered, usually many together with a firm capsule. These egg-capsules, in their various shapes, will be described presently.

Male Organs (xvi, 91). These are simpler than those of the female; the efferent canal is not divided into so many succeeding portions, but instead a copulatory organ (*penis*) is placed anteriorly, the structural peculiarities of which present much that is noteworthy.

The sperm-gland or testicle lies imbedded in the liver in the same way as the ovarium usually, only on the right side, as a flocky mass which has a greater tendency to embrace the liver than to crowd it away. Sometimes, however, it is a compact mass, and in *Paludina* it is divided into but two lobes, a larger anterior and a smaller posterior one. But in most cases the testicle is a much expanded and divided, flocky-looking, whitish mass, which like the ovarium presents an acinose structure. The efferent ducts of the simple lobes and lobules then collect together on the right side of the body into the vas deferens.

The single testicular lobules consist of a structureless tunica propria and an internal epithelium of rounded cells, in which the zoösperms are developed. In all cases where the mode of development can be followed, the contents of the epithelial cells divide into daughter-cells, in which, after the development and growth of a nucleus and the disappearance of the cell-wall, the spermatozoa are developed. The zoösperms are filiform and pointed at both ends in the spiral prosobranchs, but in *Patella*, *Chiton* and *Haliotis* the anterior end is a rounded head.

The vas deferens passes from the testicle along the columellar side of the animal into the mantle-cavity, and through the latter into the penis on the right side of the body, behind the eyes. This duct is formed externally by a strong muscular layer, and clothed within with a ciliated epithelium: it is usually dilated and coiled at its commencement.

In *Paludina* a part of the penis is lodged in the teguments of the right tentacle, which in consequence is sensibly deformed and shorter and more obtuse than the right tentacle of the female. In an Indian species of *Paludina* the penis is altogether aborted and its function transferred to the contiguous right tentacle, the extremity of which is hooked; which becomes a copulatory organ, analogous to the hectocotylized arm of the cephalopods (Wood-Mason, *Ann. Mag. Nat. Hist.*, viii, 87, 1881).

The penis is an outgrowth from the body-wall, and is not evertible and retractile in the prosobranchiates as in the pulmonates, though having at times a cavity within. It is a fleshy, often very long and thick appendage usually bent in a sigmoid form, and can be bent back under the mantle and thus be hidden.

The penis is either hollow, in which case the vas deferens proceeds to it as a closed canal passing through it to its extremity, where it opens upon a small papilla as in *Buccinum*, or it opens simply as in *Littorina*, *Oliva*, *Oncidiopsis*; or, in other cases it is a solid body upon which the vas deferens passes along in the form of a ciliated furrow continued upon it as a deep groove to its extremity, as in *Triton*, *Dolium*, *Cassis*, *Harpa*, *Voluta*, *Terebra*, *Strombus*, *Cypræa*, etc. This last and most common form of penis presents many varieties; in *Cassis*, for example, it

is pointed anteriorly, in *Dolium* it is enlarged anteriorly, in certain species of *Strombus* it has a small appendage upon the posterior side, and in *Natica* it presents at the end a whip-like (flagelliform), in *Dolium* a claw-like appendage. Usually there are large sack-like glands, which are placed on large pointed papillæ near the base of the penis; they appear therefore as a row of tubercles or processes, as in *Littorina*, *Cassis*, and *Terebra*: these glands are placed upon special finger-like outgrowths of the penis.

The copulatory act usually takes place in the spring; but in *Littorina* it occurs throughout the season, and the female has sometimes both large and minute eggs in her uterus.

The eggs come in contact with the spermatozoa and are fertilized in the oviduct or at the commencement of the uterus. The eggs consist of a dark granular yolk; a germinal vesicle and one or more germinative dots, enveloped by a thin vitelline membrane. The zoösperms penetrate this membrane through an opening termed the micropyle. They are introduced into the female tract by an act of copulation in the bulk of the spiral prosobranchs, which possess a penis; in the Trochoidea, Scuti-branchs and Cyclobranchs, however, the copulatory organ is wanting, and probably the spermatozoa discharged into the surrounding water by the male, are thence taken into the uterus. Of course the *attached* genera like *Vermetus* and *Siliquaria*, and including also *Magilus* and *Rhizochilus* in the *Purpurinæ*, cannot possibly fertilize in any other way.

Very few prosobranchiates are viviparous. The eggs are usually enclosed, a number together, in tough leathery capsules, within which they undergo their larval stage of development. These capsules are variously aggregated, according to the genera. *Littorina* deposits its eggs in gelatinous masses, and the outer portion of the albumen of each egg hardens into a sort of shell; but ordinarily an egg-capsule is formed, and then the separate ova do not possess shells, but the capsule encloses a mass of albumen which is common to all the ova within it—sometimes several hundred. In this albumen the larvæ move about before leaving the capsule for the outer world.

The number of eggs deposited by the prosobranchiate mollusca is relatively small when compared with the lamellibranchiates, but enormous in comparison with the pulmonates. A nidimental string of *Pyrula canaliculata* contained fifty capsules, each enclosing about a hundred eggs, say five thousand eggs in all. In *Buccinum* the number is much greater.

The capsules are variously shaped and aggregated, and were formerly mistaken for and described and figured as zoophytes. It will assist us in our survey of their forms to present the classification of these bodies which was proposed by the cele-

brated Danish zoologist, A. Lund, based on their form and grouping, and in which almost all the variations are characterized.

FIRST CLASS.

Masses of capsules irregular. The egg-capsules by their union form irregular masses.

First Order. The egg-capsules are attached to each other. (*Capsulæ cohærentes.*)

1. The capsules open by a cleft.

2. The capsules open by a round hole closed by a round operculum or lid.

Second Order. The egg-capsules are attached to a common membrane, which is attached to some foreign body, and are separated from each other.

1. The capsules open by a cleft.

2. The capsules open by a round hole, which is closed by a lid.

a. The capsules are sessile upon the basal membranes. (*Sessiles.*)

a. *Tubiformes.*

b. The capsules are pedunculate, connected to the basal membrane by a stalk. (*Petiolatæ.*)

a. *Oviformes.*

β. *Cyathiformes.*

γ. *Infundibuliformes.*

SECOND CLASS.

Masses of capsules regular. The egg-capsules by their union form regular masses.

First Order. The egg-capsules are attached to each other. (*Capsulæ cohærentes.*)

Second Order. The egg-capsules are attached to a common basis (*Capsulæ adhærentes.*)

a. The capsules are attached around an axis.

b. The capsules are attached longitudinally on one side of an axis.

a. *Sessiles.*

β. *Petiolatæ.*

How these capsular bodies (xvii) are developed is still a mystery.

Androgynous gastropods (Pulmonata, xviii, 8) present two distinct types of sexual organs: 1, *Monotremata*, in which the genital orifices, are confounded in a single cloaca, as in the helices; 2, *Ditremata*, in which the genital orifices are more or less distant, as in *Limnæa*.

In examining the monotremate type, we may take an Arion or Glandina, in which we find successively:—

1. An ovotestis or hermaphrodite gland. This is lobulated, and its follicles bear the ovules on the exterior and the spermatogenic cells on the interior, the production of these elements not being always simultaneous. They come together at the opening of each lobule.

2. The excretory canal; which is tortuous and ends at the posterior extremity of the deferent canal and of the matrix, in the neighborhood of the albuminiparous gland.

3. This voluminous gland is yellowish white, and much distended at the period of reproduction. Its tissues are but slightly resistant and secrete a thick liquid in which swim some globules and granulations. It is supposed that the product of this gland envelops the eggs as they arrive at the matrix—into a posterior dilatation of which its excretory canal opens. At this point, or bordering on the excretory canal of the ovotestis and the excretory canal of the albuminiparous gland, commences the separation of the genital roads; afterwards the sperms and the ovules follow distinct routes.

4. The uterus or matrix, an intestiniform canal, which adheres throughout to the first portion of the deferent canal: in the dilations of its walls are found well-developed eggs.

5. When the uterus is separated from the deferent canal, it takes the name of vagina, and borders on a vestibule which opens without.

6. Into the vagina or vestibule is inserted the more or less long *receptaculum seminis* or copulatory pouch, containing the sperms after copulation.

7. The vestibule or cloaca is a more or less spacious sac into which open the vagina, the canal of the receptaculum and the verge, and which itself opens by the external genital orifice, placed usually behind the right tentacle.

8. Returning to the deferent canal, we find it divided into two distinct portions, an adhering posterior or prostatic and an anterior or free portion. The posterior part is joined to the concave margin of the uterus: its walls, which are not always complete, are exteriorly invested with a quantity of glandular follicles. The anterior part of the canal is very narrow and tortuous, and terminates in the sac of the verge.

9. The sack of the verge (penis) is oblong, cylindrical. A retractor muscle is placed near its posterior cul-de-sac. The verge opens as we have said in the vestibule.

Such are the fundamental portions of the most simple reproductive apparatus; but in a great number of other androgyna, they become complicated by the addition of accessory organs.

At the extremity of the excretory canal of the ovotestis, and

at the point where it unites with the albuminiparous gland, exists a small cæcum, sometimes simple, as in *Bulimus*, sometimes lobulated (*Helix palliata*, *H. thyroides*, *Succinea ovata*), and the walls of which are sometimes glandular; it is believed that the ovules are fecundated at the moment of passing into its cavity.

The accessory organs to the vagina consist of narrow, elongated, ramified diverticles, united in two groups and opening on each side by a common canal. They have been called multifid vesicles, mucous glands, vaginal prostates. The number of branches of each vesicle is 61 (*Helix vermiculata*), 30 to 40 (*H. pomatia*), 25 (*H. aperta*), 12 (*H. cespitum*), 8 (*H. aspera*), 4 (*H. conspurcata*), 2 (*H. serpentina*). In *H. pisana* and *H. arbustorum* there is only found a simple vesicle on each side; finally, in *Helix lenticula* and *H. acuta*, the vesicle is unique (Moquin-Tandon). In a number of species having no mucous vesicles we find a glandular lining of the vagina or *vaginal prostate* (Zonites, *Daudebardia*). Alongside the mucous vesicles opens into the vagina the sac of the curious *dart* (xviii, 9, 10), which consists of one or two ovoid purses having muscular walls, and within which are secreted a calcareous object, like a sharpened point or lance-head, with trenchant edges, rounded base, and channeled sides. This *telum veneris* is expelled at the moment of copulation and buries itself in the teguments of the snails in coitu.

The canal of the copulatory pouch usually has a diverticle called the copulatory branch; its size is narrow and uniform, and its length sometimes considerable (*Helix Niciensis*).

The vestibule is in relation with some appendages, the use of which is not known; such are the horn-like appendages of *Parma-cella*. The genital cloaca is encircled by mucous glands in *Limax marginatus*: Moquin-Tandon designates them under the name of *vestibular prostates*.

The deferent canal may be encircled with prostatic glands, as well as its free portion.

The cul-de-sac of the penis-pouch is usually provided with a very long cylindrical appendage or *flagellum*, in which is formed the spermatophore. Nevertheless, a spermatophore equally exists in species having no flagellum; in which case, the secretion of this envelope of the seminal fluid takes place in the deferent canal (Dubreuil). The prostates or mucous glands open in the copulatory sac in *Orthalicus* and *Liguus*.

In order to understand the disposition of the genital organs in the androgyna having separate orifices, or *ditremata*, we will take for type those of *Limnæa*. The hermaphroditic gland and its excretory canal have the same disposition as in the *monotremata*. The albuminiparous gland is placed at the posterior

extremity of the uterus—which adheres very slightly to the first portion of the deferent canal, so that a slight traction suffices to separate them; consequently their walls are complete.

We find in the course of the uterus a yellowish pocket having glandular walls, in front of which the uterus swells, constituting the egg-reservoir. This dilatation contracts to form the vagina, in which opens the neck of the copulatory sac. The female orifice opens at the base of the neck near the pulmonary opening.

The deferent canal, in its adherent portion, is first flattened, then dilates and becomes pyriform. Its anterior portion is narrow cylindrical, and gains the base of the verge after having traversed a muscular mass in which it appears to lose itself. The male genital orifice is placed behind the right tentacle.

In *Limnæa* and *Planorbis* the inter-muscular course of the anterior portion of the deferent canal is very short, but in *Vaginula* it is very long. This canal is not always complete; in *Oncidium*, *Oncidiella*, *Aplysia*, etc., it is replaced by a simple gutter placed below the body, on the right side of the foot, or at the superior right side of the neck.

As in the monotremata, we find also in the ditremata accessory organs annexed to the reproductive system. The excretory canal of the ovotestis develops large and numerous glands (*Ancylus*); a seminal vesicle is inserted in the deferent canal (*Vaginula*); one or several diverticular appendages open in the vagina (*Oncidiella*, *Melampus*); very numerous mucous or multifid vesicles open in the sack of the verge (*Vaginula*); an extremely long flagellum is inserted in the posterior extremity of the penis-sack (*Peronia*), etc.

The Pteropoda are androgynous, their genital system resembling that of the Opisthobranchiates or of the ditremate pulmonates. In *Hyalæa*, there exists in effect: a rather large hermaphrodite gland, the excretory canal of which is provided with a long epididymic cæcum; a matrix to the posterior part of which adheres a sort of albuminiparous gland; a vagina where the copulatory pouch opens. The female is separated from the male orifice. The deferent canal is separate from the matrix and gains the verge, the orifice of which is near the mouth. In the ditremate pulmonata and the opisthobranchiates the copulatory act, of course, cannot be reciprocal between two individuals; one of them must take the part of female, the other of male; but a third can be male for the second, and so on, *ad infinitum*. Such is the mode of copulation in *Aplysia fasciata*. Fischer has seen chains formed by six individuals, the first functionally as female only, the following ones as male with the preceding and as female with the succeeding individual, the last fulfilling the rôle of male only. Geoffroy has seen similar chains formed by the *Limnæans*. In *Helix* copulation is reciprocal, each indi-

vidual playing the part of male and female at the same time; the genital vestibule is thrust out, the penis is unrolled like the finger of a glove and introduced into the vagina. The sperm is surrounded sometimes by an elongated filiform capsule, which is dilated for its anterior third with crenulated edges, or salient ridges, and which is called a spermatophore or capreolus. Such spermatophores are found in *Arion*, *Parmacella*, *Peltella*, *Hyalina*, *Bulimulus*, and in a large number of *Helices*, but in some of the latter genus they do not exist.

The presence of a spermatophore in the verge of each individual during copulation, evidently proves that fecundation must be reciprocal; nevertheless the pulmonates may copulate several times, as Van Beneden has found two spermatophores in the copulatory pouch of a *Parmacella*, and Fischer has seen four in that of *Bulimulus Delattrei*.

I have watched the copulatory act in American *Helices*, confined under a bell glass, and have been amused by the stupidity with which two individuals, each similarly minded, would continue to crawl around each other for many minutes, both so desirous to play the active part that neither was willing to remain immobile the moment necessary to secure the juxtaposition of their organs.

The spermatophore is formed in the deferent canal (*Hyalina*), or in the verge or its flagellum (*Helix*); after its dissociation in the copulatory pouch, the sperm is set at liberty; the spermatozoa enter the canal of this pouch and pass into the uterus; finally arriving in the epididymic cæcum, where they fecundate the ovules.

Terrestrial mollusks lay but few eggs; which are covered usually by a soft skin, but in the *Testacella* and tropical species of *Bulimus* and *Achatina* the egg is protected by a calcareous shell. The group *Borus*, including the largest species of *Bulimus*, inhabits the tropical regions of Brazil; the eggs of these shells are about an inch in length, or fully the size of a pigeon's egg (xvii, 100), with a shell of about the same thickness. The natives eat them. In a similarly isolated group of *Achatina*, inhabiting tropical Africa the eggs are equally as large as *Borus*. Generally the eggs are laid in a shallow hole dug in the ground and covered over, but some of the arboreal Philippine Island *Bulimi* construct a rude nest by curling up the leaf of a tree, in which they oviposit.

Fresh-water pulmonates, *Limnæa*, *Physa*, etc., lay from twenty to one hundred eggs, *Ancylus*, five or six; these are enveloped together in a gelatinous material.

The opisthobranchiates form a spirally rolled ribbon-like capsule for their eggs; such are those of *Aplysia*, *Doris* (xvii, 97), *Bullæa*, *Eolis*. A somewhat similarly shaped capsule,

consisting of two-thirds of a circle, narrowed into a neck at top, is produced by the American Naticas, *N. heros* and *N. duplicata* (xvii, 95). It is built up of eggs cemented together by sand and a gelatinous material; and is very common on our sea-beaches; the egg-pouches of *Nassa* are frequently attached to its inner wall.

Janthina attaches its eggs to the under side of a float (xvii, 99) composed of numerous cartilaginous air-vesicles, and secreted by its foot. *Lamellaria perspicua* digs a cavity in the colonies of certain compound Ascidians, upon which it usually feeds, and there oviposits.

Some Polynesian *Helices* (Endodonta) having a large umbilicus or basal axial opening in their shells, oviposit in it and cover the aperture with a thin diaphragm to prevent them from falling out. The eggs of *Hipponyx*, *Capulus* and *Calyptræa* are attached to the body of their mother, who thus appears to protect them, like the *Janthina*. On the other hand, the *Limnæids* not only take no care of their eggs, but are known to devour them.

Scaphopoda. The sexual organs, like some other portions of their anatomy, are more nearly related to the bivalve than to the encephalous mollusca. The sexes are separated, and the organs are composed of two symmetrical glands, the products of which are excluded through a posterior orifice, and through the open posterior end of the shell.

Acephala or *Pelecypoda* (xviii, 11, 17; xxii, 64). The sexual organs are composed of genital glands and vector channels. The genitals are symmetrical, paired and placed at the sides and base of the visceral mass; they are sometimes prolonged to the foot, sometimes to the lobes of the mantle. "*Pecten maximus*, *P. Jacobæus*, *P. glaber*, *Cardium*, *Pennanti*, *Pandora inæquivalvis*, *Anodonta cellensis* and *Ostrea edulis* have been recorded as hermaphrodite, and *Pecten varius*, *Cardium edule*, and most species of *Unio* as diœcious. But inasmuch as the male and female glands are not developed at the same time, it follows that an individual examined at different epochs may appear to be male or female or hermaphrodite. It is probable that some of the above determinations are therefore erroneous, and that more extended observation will greatly increase the number of diœcious bivalve mollusks. The difficulty in determining sex in these animals is increased by the fact that a single excretory canal serves for both ovules and spermatozoa. The male gland is whitish, the ovary usually reddish (*Spondylus*, *Janira*, *Mytilus*); these two glands are lobulated and generally distinct enough, but in the European *Ostrea* the spermatoc and ovarian follicles are contiguous and, so to say, confounded."

"In some species (European *Ostrea*) the disposition of the

two elements of the genital gland is such that fecundation occurs partially before exclusion, but on account of the inequality in time of development of the sexual elements, the spermatozoa are usually transported by the surrounding water and serve to fecundate other individuals. In the diœcious bivalves the spermiatic fluid is always conveyed by the water, as there is no act of copulation, and fecundation takes place probably in the pallial or branchial cavity of the females."

I have recorded the above observations of Dr. Fischer, which agree with the current belief upon the subject of sex in the lamellibranchiates, but the recent observations of Brooks* and Ryder upon the development of the American oyster, show that in that species at least, the sexes are always distinct. Mr. Ryder has established likewise the diœcious nature of *Mya arenaria*.

The number of eggs produced by the pelecypods is prodigious, amounting to a million or more, in the European *Ostrea*, and from ten to sixty millions in the American oyster; from 400,000 to 2,000,000 in *Anodonta*; perhaps as many as 12,000,000 in *Teredo*. Notwithstanding these enormous quantities a certain care of the eggs is exercised by *Unio*, *Anodonta* and *Sphærium*, which retain, hatch and protect their young for a period in their exterior branchiæ (*branchial uterus*). Dr. Lea has observed all the four leaves of the branchiæ filled with ova in several species of *Unio*, recalling the incubatory pouch of the marsupial mammalia.†

DEVELOPMENT.

The researches of John Hunter led him to the conclusion that each stage in the development of the highest animals corresponded to the permanent form of some one of the lower orders. Since his time a number of eminent investigators have partially confirmed this generalization, and more exactly defined it by a larger induction of facts. Woodward thus states it:

"In the earliest period of existence all animals display one uniform condition; but after the first appearance of special development, uniformity is only met with amongst the members of the same primary division, and with each succeeding step it is more and more restricted. From that first step, the members of each primary group assume forms and pass through phases which have no parallels, except in the division to which each belongs. The mammal exhibits no likeness, at any period, to the *adult* mollusk, the insect or the star-fish; but only to the ovarian stage of the invertebrata, and to more advanced stages

* Johns Hopkins Laboratory Studies, i, pt. 4.

† Raymond has observed that an Algerian fluviatile gastropod (*Melania tuberculata*), carries its young in the branchial cavity, and that these are accustomed to quit and re-enter this temporary lodging.

of the classes formed upon its own type. And so also with the highest organized mollusca; after their first stage they resemble the simpler orders of their own subkingdom, but not those of any other group."

The molluscan *ovum* (xix) consists of a colored yolk (*vitellus*), surrounded by albumen and either enclosed separately by a shell, or several together by a common envelope. On one side of the yolk is a pellucid spot, termed the *germinal vesicle*, having a spot or *nucleus* on its surface. This germinal vesicle is a nucleated cell, capable of producing other cells like itself; it is the essential part of the egg, from which the *embryo* is formed; but it undergoes no change without the influence of the *spermatozoa*. After impregnation, the germinal vesicle, which then subsides into the centre of the yolk, divides spontaneously into two; and these again divide and subdivide into smaller and still smaller globules, each with its pellucid centre or nucleus, until the whole presents a uniform granular appearance (*morula stage*). The next step is the formation of a ciliated *epithelium* on the surface of the embryonic mass; movements in the albumen become perceptible in the vicinity of the *cilia*, and they increase in strength, until the embryo begins to revolve in the surrounding fluid.*

Up to this point nearly the same appearances are presented by the eggs of all classes of animals—they manifest, so far, a complete "unity of organization." In the next stage, the development of an organ, fringed with stronger *cilia*, and serving both for locomotion and respiration, shows that the embryo is a *molluscos animal*; and the changes which follow soon point out the particular *class* to which it belongs. The rudimentary *head* is early distinguishable by the black eye-specks; and the *heart* by its pulsations. The digestive and other organs are first

* According to the observations of Professor Lovén (on certain bivalve mollusca), the ova are excluded immediately after the inhalation of the spermatozoa, and apparently from their influence; but impregnation does not take place within the ovary itself. The spermatozoa of *Cardium pygmaeum* were distinctly seen to penetrate in succession the outer envelopes of the ova, and arrive at the vitellus, when they disappeared. With respect to the "germinal vesicle;" according to Barry, it first approaches the inner surface of the vitelline membrane, in order to receive the influence of the spermatozoa; it then retires to the centre of the yolk, and undergoes a series of spontaneous subdivisions. In M. Lovén's account it is said to "burst" and partially dissolve, whilst the egg remains in the ovary, and before impregnation; it then passes to the centre of the yolk, and undergoes the changes described by Barry, along with the yolk, whilst the *nucleus* of the germinal vesicle, or some body exactly resembling it, is seen occupying a small prominence on the surface of the vitelline membrane, until the metamorphosis of the yolk is completed, when it disappears. It has been named polar globule, and is supposed to be expelled by the micropyle.

"sketched out," then become more distinct, and are seen to be covered with a transparent shell. By this time the embryo is able to move by its own muscular contractions, and to swallow food; it is therefore "hatched," or escapes from the egg.

Cephalopoda (xix, xx, 39-42). "In the dibranchiates the yolk undergoes partial division, and the blastoderm (yolk-sac) formed upon the face of it by the smaller blastomeres, spreads gradually over the whole ovum, enclosing the larger and more slowly dividing blastomeres. The mantle makes its appearance as an elevated patch in the centre of the blastoderm, whilst the future arms appear as symmetrically disposed elevations of the periphery, on each side of the mantle. Between these and the edge of the mantle, two longitudinal ridges mark the rudiments of the epipodia, while the mouth appears in the middle line in front of the mantle, and the anus, with the rudiments of the gills, behind it. The rest of the blastoderm forms the walls of a vitelline sack, enclosing the larger blastomeres.

"The pallial surface now gradually becomes more and more convex, the posterior margin of the mantle growing into a free fold, which encloses the pallial chamber and covers over the gills.

"The internal shell is developed in a sac formed by an involution of the ectoderm of the mantle. The epipodia unite behind, and give rise to the funnel, while the antero-lateral portions of the foot grow over the mouth, and thus gradually force the latter to take up a position in the centre of the neural face, instead of in front of it. The yolk-sack gradually diminishes, and the contained blastomeres are finally taken into the interior of the visceral sac, into which the alimentary canal is gradually drawn." —HUXLEY, "Anatomy of Invertebrated Animals."

At a later period of development, respiratory movements are performed by the alternate dilatation and contraction of the mantle, and the position of the ink-bag is revealed by its color through the transparent flesh. The shell of the young *Sepia*, observes Kölliker, by the time it is prepared to leave the nidamental capsule has already formed, but except the nucleus, which is calcified, its fine layers are horny and transparent. The fins are proportionally broader than those of the mature animal.*

The development of *Nautilus*, equally with its nidus is unknown.

Gastropoda (xx, 43-53). The transformation of the egg into the embryo is preceded by division of the yolk mass into blasto-

* For a fuller account of cephalopodous development, see an excellent paper on that of *Loligo Pealei*, by W. K. Brooks, *Anniversary Memoirs*, Boston Soc. Nat. Hist., 1880.

meres (cells), which begins immediately after fertilization and is speedily completed (Morula stage). The yolk assumes the appearance of a cluster of round nucleated cells, the large ones internal, the smaller external; forming the embryo—except a portion which remains as nutritive material. The yolk first loses its spherical form, elongates somewhat, develops upon its entire surface a delicate ciliary covering, and begins its wonderful rotary movement.* At the anterior part of the body a circlet or crown of long cilia arises; the portion of the body supporting this is then elevated into a ridge, then a ring, and finally it develops on each side into a rounded lobe. Both lobes together present somewhat the appearance of the figure 8: these are the vela which Forskål first described as the organs of locomotion of the univalve molluscan larvæ. Most of the prosobranchiate and opisthobranchiate larvæ are velamentous. Immediately below the velum the mouth is developed as an invagination; at the posterior end the anus is similarly formed; both open into the intestinal cavity which has been formed by the displacement of the large yolk-cells in the centre. An intestine is now present, and the large cells which are somewhat heaped up posteriorly, become in large part the liver and intestinal wall. A body-cavity between this large-celled intestinal wall and the small-celled body-wall is not yet present, and originates later by a separation of the two walls and the appearance of a fluid between them.

Below the mouth the foot arises as a blunt ciliated appendage, whilst the ciliated covering of the rest of the body has become lost. The velum, that at first surrounded the fore-part of the body is more elevated to the dorsal side after the appearance of the mouth, since the mouth is not placed in the middle of the velum, but beneath its narrow portion, and is dorsally overhung by the velum, whilst ventrally the foot extends beyond it. The body becomes more elongate, and soon at its posterior dorsal portion the delicate, hyaline, cup-like shell appears, in which also a distinct laminated structure may be detected; at the posterior part of the foot, the operculum appears at the same time. The sense organs are now developed; at each side in the velum the tentacle arises as a papilla; internally by the side of the œsophagus the auditory vesicles arise, the otoliths then appear therein; and immediately thereafter, or at the same time, alongside of the tentacles the eyes are formed, which, at first, like the organs of hearing are vesicles, lined with cilia internally, the lens appearing later. The central portions of the nervous system, the ganglia around the œsophagus, now become visible. Along

* The blastoderm becomes invaginated, and we see the *gastrula* stage in the opisthobranchiate genera Polycera, Doris, etc.

the border of the shell the body-wall is raised into a ridge, the beginning of the mantle, and, as the shell grows farther forward, the intestine in most prosobranchiates (not in Chiton), instead of terminating posteriorly, begins to be pushed forwards, so that the anus is likewise advanced with the border of the shell to the right side of the body.

The pharynx now appears as a distinct portion of the animal and within it, the different parts of the lingual membrane may be distinguished as the middle, inter, and lateral plates, and according to Troschel's observation, the genus to which the larva belongs may be already determined by the teeth. One may already notice the commencement of the spiral winding of the shell, and within it is contained one loop of the intestine and many large cells or yolk-spheres, which become the liver. A larval shell exists even in those mollusks (Nudibranchiates) which have no shell in the adult state; it is closed by means of an operculum.

As soon as the anus commences to be pushed forwards and the intestine becomes a distinct canal, the body-cavity begins to appear with blood in it. There is as yet nothing to be seen of the heart, and the circulation of the blood is effected by the contraction and dilatation of the hollow foot, or often by means of an elevation on the neck, consisting of a meshwork of fibres, the cervical vesicle. By means of the heart, as soon as it is developed, the fluid in the body-cavity, the blood, is put into motion, but often, as in *Paludina*, this circulation is assisted, and probably more effectively, by the contraction and dilatation of the foot.

At this stage the larvæ mostly leave the albumen of the egg-corpuscles, in which, up to this time, they have been enclosed, and swim freely about by means of their velum. Finally, the mantle-cavity is formed; the mantle, heretofore simply a ridge around the front of the shell, now extends itself from the body as a fold and covers, with the shell, the mantle or respiratory cavity, in the base of which, a contractile structure—the heart—may soon be observed. The foot is developed still further, the velum, the only exclusively larval organ, slowly disappears, the tentacles are prolonged and in this way the swimming larva slowly becomes the creeping animal—of which the various organs finally attain maturity.

Prof. W. B. Carpenter has observed* that whilst a capsule of *Purpura lapillus* contains from 500 to 600 vitelline bodies, nevertheless only from 12 to 30 embryos are produced, each of these having from 20 to 30 times the bulk of the ovum from which it sprang; so that the material contained in the original mass of

* *Rept. Brit. Assoc.*, 108, 1854.

eggs is evidently appropriated by the comparatively few embryos which are thus developed at its expense. Prof. Carpenter examined a large quantity of capsules, in which a considerable number of small, free embryos presented themselves before the conglomeration of the great mass of the ova, so that he could not doubt they were generated independently of it. The embryos soon attach themselves to the conglomerate yolk-mass, and by the action of their cilia, the small segments of which it is composed are driven down into their interior, which is soon distended by them. The bodies which coalesce after segmentation, Prof. Carpenter regards as imperfectly fertilized ova, and they evidently supplement the insufficient supply of nutriment contained in the yolk-sack of each developing embryo. A similar consumption of a portion of the ova takes place in *Buccinum* and *Nassa* and very probably in a large portion of the prosobranchiates.

Generally, the shell and operculum developed within the egg-capsule are retained by the animal, forming simply the nucleus of the adult structure, but in a few cases a temporary shell and operculum are provided, which are eventually lost. Animals in this larval condition were formerly described as distinct genera of pelagic gastropods, until Krohn, and after him Macdonald,* showed their true relationship; in this the lingual dentition became an important agent to indicate the connection with adult forms. Krohn discovered at Messina a curious mollusk which he called *Echinospira* (xx, 49-50), and which proved to be the larval state of *Marsenia conspicua*. He found the nucleus of the permanent shell to be developed within the spiny nautiloid larval shell, and that the latter was eventually cast off. I figure some other pelagic larval mollusks: *Macgillivraya*, with its curious six- or eight-lobed tentaculiform velum (xx, 44-46), which is the larva of *Dolium*, and *Cheletropis* = *Sinusigera* (xx, 47-48) which, on account of its dentition has been (probably erroneously) referred to the *Muricidæ*;† but in all the egg-capsules of *Murex* which I have examined the contained shells are miniatures of the adults. Mr. Arthur Adams has referred a *Cheletropis* to *Purpura biserialis*, and it is just possible that the species belongs to the *Purpurinæ*. Investigations of the transformations of free swimming larvæ are made with difficulty, and it will probably be many years before we shall have acquired a sufficient body of facts to understand the conditions

* Macdonald, On Metamorphosis of Mollusca, *Linn. Trans.* xxii, 241; xxiii, 69.

† *Chiropteron semilunare*, Sars (*Beskriv. og Jagtta gelser*), t. 14, f. 38, 1835), is probably the larva of *Aporrhais*. *Mörch, Ann. Mag. N. Hist.*, 3d ser., xvi, 78, 1865.

under which a large portion of the prosobranchiates undergo this larval transformation after exclusion, whilst in other genera the newborn mollusk is the epitome of the adult.

In the larval Chiton the velum is replaced by a crown of cilia, and eyes are present although the adult is blind. The shell, when it appears, is the miniature of the mature form.

In the pulmonata the velum is rudimentary, represented by a ciliated tuft on each side of the mouth. In *Limax* there exists on the dorsal posterior extremity of the body a pedunculated vesicle, the contractions of which, alternating with those of the vitelline sac, produce a sort of circulation which diminishes and disappears as the heart is formed. The embryonic pulmonata possess primitive kidneys or *Wolfian Bodies*, consisting of paired tubes, curved, without communication one with the other, and the walls of which are provided with secretory cells. These organs are formed by a small invagination of the ectoderm. The embryonic shell of the pulmonates constitutes the apex of the adult shell; where it is usually distinguishable by smoothness of surface, hyaline and colorless appearance.

Pteropoda (xx, 53). Most of these in the larval state resemble those of the marine gastropods. They have a ciliated velum and an operculated shell. The velum atrophies on the development of the wings. The gymnosomate pteropods (*Pneumodermon*, *Clio*), pass through a stage during which they are provided with three girdles of cilia, and resemble the annelid embryos—as do those also of the Dentalium.

Scaphopoda (xx, 54, 55). The larval Dentalium is provided with several circles of cilia. Its shell is constituted at first of two symmetrical portions, with margins in contact; these finally unite to form the single tube of the tooth-shell, an elongated cylinder open at each end.

Pelecypoda (xxi). The young bivalves are hatched before they leave their parent; the oviducts open into the dorsal channels, and the eggs are received into the gill-tubes and there retained until the escape of the young mollusk. In *Unio* and *Anodonta* (xviii, 11), the outer gills only receive the eggs, with which they are completely distended in the winter months. In *Sphærium* the inner gills form the *marsupium*, containing from ten to twenty fry: some of these remain until nearly a fourth the length of their parent.

The forms which young bivalves pass through, present distinct differences in several families, so that even in the present state of embryological knowledge, some five or six types of development are known. Even in the same family there may be a great dissimilarity, as in the case of the marine and fresh-water forms of the *Mytilidæ*. The following account refers to the type to which the young of *Crenella* belong. At first they have a swim-

ming disk, fringed with long *cilia*, and armed with a slender tentacular filament (*flagellum*). At a later period this disk disappears progressively as the labial palpi are developed; and they acquire a foot, and with it the power of spinning a byssus. They now have a pair of eyes situated near the labial tentacles which are lost at a further stage, or replaced by numerous rudimentary organs placed more favorably for vision, on the border of the mantle.

The shells of the embryonic Uniones and Anodons (xx, 56, 57), are so dissimilar to those of the adults, that they were at one time considered to be parasites (*Glochidium*). The valves of the shell are usually triangular, with a flattened hinge-line and they frequently have incurved hooks on the basal margin, by the help of which the larvæ, after they leave the parent, attach themselves to its shell, or to fishes and other floating bodies. In this position they undergo metamorphosis, and eventually fall off and sink to the bottom as minute fresh-water Mussels. The young of some species are attached by a filament, and Dr. Lea believes that they are always *unimusculose* (monomyary), the muscle dividing during metamorphosis.*

The development of the oyster (xx, 60-63), presents some interesting particulars. The embryo, at first spherical, becomes cordiform, then two or three vibratile cilia appear on its surface, and a transparent tract indicates the place of the hinge—in the vicinity of which is formed a calcareous deposit, the first indication of the valves. The velum soon greatly develops, so that its complete retraction is not possible. By the aid of this organ the animal swims rapidly, but without knocking the surrounding embryos. The mouth is encircled by a crown of cilia. The velum finally disappears, or is possibly transformed into the labial palpi. Finally the shell, until now equivale and free becomes fixed for life, and from this moment commences the normal life of this mollusk.†

In *Pisidium*, the oral extremity of the embryo is velated. On its dorsal face the tegument is raised to form a mantle, at the centre of which is produced by invagination a small sac or *preconchylian gland*, having a temporary existence (Lankester). This gland occupies the place of the ligament; the shell is afterwards developed on the surface of the mantle under the form of a

* Lea, Obs. on Unio, vi, 43.

† The eggs of the American oyster (*O. Virginica*), are fertilized outside the body of the parent, and the young swim at large during the period in which the fry of the European species (*O. edulis*) are sheltered in the mantle of the parent. Segmentation of the vitellus in the first named is, according to Brooks, completed in about two hours.—*Am. Jour. Science*, xviii, 425, 1879.

chitinous cuticle. There exists, nearly always, a byssal gland at the base of the foot.

REPRODUCTION OF DESTROYED ORGANS.

It appears from the experiments of Spallanzani, that snails, whose ocular tentacles have been destroyed, reproduce them completely in a few weeks; others have repeated the trial with a like result. But there is some doubt whether the renewal takes place if the brain of the animal be removed as well as its horns. Madame Power has made similar observations upon various marine snails, and has found that portions of the foot, mantle, and tentacles, were renewed. Mr. Hancock states that the species of *Eolis* are apt to make a meal off each other's *papillæ*, and that, if confined in stale water, they become sickly and lose those organs; in both cases they are quickly renewed under favorable circumstances.

The Cephalopoda frequently lose a portion of an arm or the entire limb in the course of their active existence, but soon develop another from the stump of the destroyed member, and only differing from it in being less colored.

In some cases mollusks can spontaneously detach portions of their body. I have already shown in the chapter on sexual organs how the hectocotylized arm of the Octopus becomes detached from its owner and remains within the pouch of the female, and that a similar specialized arm develops in due time to take the place of the lost member; only to detach itself in turn. Quoy and Gaimard several times saw the *Harpa ventricosa* amputate the posterior portion of the foot by muscular contractions, the lost part being subsequently replaced by growth. In two Cuban *Helices* also (*H. crassilabris* and *H. imperator*), Dr. Gundlach has seen a similar amputation and somewhat rapid regeneration.

The bivalve genera *Solen* and *Solecurtus* readily lose a portion of their siphons. Fischer has often found the detached extremities of siphons alongside the beds of *Solen marginatus* in the Basins of Arcachon.

I have already considered the renewal of fractured portions of the shell (pp. 20, 32) and operculum (p. 49), as well as the abnormal duplication of both (p. 52).

HABITS AND ECONOMY OF THE MOLLUSCA.

“Every living creature has a history of its own; each has characteristics by which it may be known from its relatives; each has its own territory, its appropriate food, and its duties to perform in the economy of nature. Our present purpose, however, is to point out those circumstances, and trace the progress of those changes which are not peculiar to individuals or to species, but have a wider application, and form the history of a great class.

“In their infancy the molluscous animals are more alike, both in appearance and habits, than in after-life; and the fry of some of the aquatic races are almost as different from their parents as the caterpillar from the butterfly. The analogy, however, is reversed in one respect; for whereas the adult shell-fish are often sedentary or ambulatory, the young are all swimmers; so that by means of their fins and the ocean-currents, they travel to long distances, and thus diffuse their race as far as a suitable climate and other conditions are found. Myriads of these little voyagers drift from the shores into the open sea and there perish; their tiny and fragile shells becoming part of a deposit constantly accumulating, even in the deepest parts of the sea.

“Some of these little creatures shelter themselves beneath the shell of their parent for a time, and many can spin silken threads with which to moor themselves, and avoid being drifted away. They all have a protecting shell, and even the young bivalves have eyes at this period of their lives, to aid them in choosing an appropriate locality.

“After a few days, or even less, of this sportive existence, the sedentary tribes settle in the place they intend to occupy during the remainder of their lives. The tunicary cements itself to rock or sea-weed; the ship-worm adheres to timber, and the Pholas and Lithodomus to limestone rocks, in which they soon excavate a chamber which renders their first means of anchorage unnecessary. The Mya and razor-fish burrow in sand or mud; the mussel and Pinna spin a byssus; the oyster and Spondylus attach themselves by spines or leafy expansions of their shell; the Brachiopoda are all fixed by similar means, and even some of the gastropods become voluntary prisoners, as the Hipponyx and Vermetus, the Rhizochilus and Magilus.

“Other tribes retain the power of traveling at will, and shift their quarters periodically, or in search of food; the river-mussel drags itself slowly along by protruding and contracting its flexible foot; the cockle and Trigonia have the foot bent, enabling them to make short leaps; the scallop (*Pecten opercularis*) bounds rapidly by opening and shutting quickly its tinted

valves, and the larger species are thus able to make leaps of one or two yards; the nearly related *Lima* vaults through the water like the butterfly through the air.—(MOQUIN-TANDON.) Nearly all the gastropods creep like the snail, though some are much more active than others; the pond-snails can glide along the surface of the water, shell downwards; the nucleobranchs and pteropods swim in the open sea. The cuttle-fish have a strange mode of walking, head downwards, on their outspread arms; they can also swim with their fins, or with their webbed arms, or by expelling the water forcibly from their branchial chamber; the calamary can even strike the surface of the sea with its tail, and dart into the air like the flying-fish.—(OWEN.)

“By these means the mollusca have spread themselves over every part of the habitable globe; every region has its tribe; every situation its appropriate species; the land snails frequent moist places, woods, sunny banks and rocks, climb trees, or burrow in the ground. The air-breathing limneids live in fresh water, only coming occasionally to the surface; and the auriculas live on the sea-shore, or in salt-marshes. In the sea each zone of depth has its molluscos fauna. The limpet and periwinkle live between the tide-marks, where they are left dry twice a day; the *Trochus* and *Purpura* are found at low water, amongst the sea-weed; the mussel affects muddy shores, the cockle rejoices in extensive sandy flats. Most of the finely-colored shells of the tropics are found in shallow water, or amongst the breakers. Oyster-banks are usually in four or five fathoms water; scallop-banks at twenty fathoms. The *Terebratulæ* are found at still greater depths, commonly at fifty fathoms, and sometimes at one hundred fathoms or more, even in Polar seas. The fairy-like *Pteropoda*, the oceanic snail, and multitudes of other floating mollusks, pass their lives on the open sea, forever out of sight of land; whilst the *Litiopa* and *Scyllæa* follow the gulf-weed in its voyages, and feed upon the green delusive banks.”—(WOODWARD.)

Parasitism is rare among mollusks, and only exists in connection with the Echinodermata and Cœlenterata. The best known parasitic genus is *Stylifer*, a little gastropod, numerous in species. *S. Turtoni* attaches itself to the spines surrounding the anus of different British species of *Echinus* (sea-urchins); *S. astericola* of the Galapagos Islands digs itself a comfortable dwelling in the tissues of an *Asterias* (Cuming); *S. Orbigny* lodges itself in the spines of *Cidaris*, causing a malformation. Some of the nearly-related genus *Styliferina* live on *Ophiura*, and certain species of *Eulima* in *Holothuria*. *Entoconcha mirabilis* is found floating freely in the body of *Synapta*, in which it develops its little operculated shells. J. Müller, who discovered this curious parasite, supposed that there existed in *Synapta* an

alternating generation, one of the forms being the echinoderm, the other the mollusk; but this theory is not tenable, and it is certain that Entoconcha is a gastropod, but whether related to Eulima, or whether the larva of a nudibranchiate, has not been determined. Some species of Odostomia are scarcely obtained elsewhere except fixed to the ears of the valves of Pecten. They may live on the secretions of that mollusk, or possibly upon minute animals found upon the valves.

Magilus, Leptoconcha, Cryptobia, Coralliophila, Rhizochilus, Pedicularia, etc., live among polyps and on Alcyonaria; and many Eolidians remain attached to Hydrozoa and Bryozoa. *Lamellaria perspicua* feeds on Leptoclinum, one of the compound ascidians, and deposits its eggs in a cavity which it digs in the colonies of these animals.

Among bivalves, the European species *Montacuta substriata* is found attached to the spines of sea-urchins; the *Lepton parasiticum*, of Kerguelen's Island has been found in the vicinity of the mouth of a Hemiaster (Dall); *Modiolaria marmorata* is nearly always encysted in the teguments of simple ascidians; Vulsella, and Crenatula and a number of species of other genera live in sponges; Tridacna and Pedum on coral.

In fresh waters, young Unios and Anodons fix themselves on the opercula, the lips and fins of fishes (Leuciscus, Gobio). Their larval byssus and the spiny border of their larval shells favor this parasitism. The true nature of these young mussels was at first mistaken, and they were described under the name of *Glochidium parasiticum*.

Food. The food of the mollusca is either vegetable, or animal. Nearly all the land snails are vegetable-feeders, and their depredations are but too well known to the gardener and farmer in Europe where many a crop of winter corn and spring tares has been wasted by the ravages of the "small gray slug." In the drier climate of the United States where the snails are mostly compelled to seek the shade and dampness of forests, they are seldom destructive to crops. They have their likings, too, for particular plants, most of the pea-tribe and cabbage-tribe are favorites, but they hold white mustard in abhorrence, and fast or shift their quarters while that crop is on the ground. Some, like the "cellar-snail," feed on cryptogamic vegetation, or on decaying leaves; and the slugs are attracted by fungi, or any odorous substances. The round-mouthed sea-snails (holostomata) are nearly all vegetarians, and consequently limited to the shore and the shallow waters in which sea-weeds grow. Beyond fifteen fathoms, almost the only vegetable production is the nullipore; but here corals and horny zoophytes take the place of algæ, and afford a nutritious diet.

The whole of the bivalves live usually on infusoria, or on

microscopic plants, brought to them by the current which their ciliary apparatus perpetually excites; such, too, must be the sustenance of the *Magilus*, sunk in its coral bed, and of the *Calyptræa*, fettered to its birth-place by its calcareous foot. Fresh-water bivalves, *Sphærium*, *Unio*, are known to have a liking for decaying animal food; the former being frequently found attached to it, the latter often burrowing in the putrescent mass.

The carnivorous tribes prey chiefly on other shell-fish, or on zoophytes; since, with the exception of the cuttle-fishes, their organization scarcely adapts them for pursuing and destroying other classes of animals. One remarkable exception is the *Testacella*, which preys on the common earth-worm, pursuing it in its burrow.

Most of the siphonated univalves are animal-feeders; the carrion-eating stromb and whelk consume the fishes and other creatures, whose remains are always plentiful on rough and rocky coasts. Many wage war on their own relatives, and take them by assault; the bivalves may close, and the operculated nerite retire into his home, but the enemy, with rasp-like tongue, armed with siliceous teeth, files a hole through the shell—vain shield where instinct guides the attack! Of the myriads of small shells which the sea heaps up in every sheltered “ness,” a large proportion will be found thus bored by the whelks and purples; and in fossil shell-beds, such as that in the Touraine, nearly half the bivalves and sea snails are perforated—the relics of ante-diluvian banquets. The perforation is always made at a point covering the essential organs of the victim. In the acephala it is found at the central part of one valve, usually near the beaks, in the encephala about the middle of the length of the shell. Boring mollusks are a veritable plague to the owners of oyster-banks: the *Murex erinaceus* in Europe, the *Urosalpinx cinerea* on the Atlantic and the *Purpura crispata* on the Pacific coasts of the United States are enemies upon whom the oyster-fisher wages constant warfare. The carnivorous gastropods often pay the penalty which they inflict, and not unfrequently the shell of the *Natica duplicata* may be found, bored through at a spot where its late inhabitant was powerless to repel the intruder.

There are certain carnivorous genera among the terrestrial gastropods: these are (besides the *Testacella*), *Daudebardia*, *Glandina*, *Ennea*, *Rhytida*, etc. They live on small species of the herbivorous genera, *Helix* and *Bulimus* which they detach from their shells by means of their tongues. Sometimes they swallow both shell and proprietor; as Fischer found an *Opeas* intact in the stomach of a *Glandina*. A number of usually herbivorous species of terrestrial mollusks have developed carnivorous instincts when imprisoned with other species.

The *Aplysia* or sea-hare will, in captivity, eat its eggs, soon after laying them; and *Limnæa* has been known to eat its progeny when urged by hunger: indeed, many of the terrestrial and fluviatile mollusks, herbivorous by habit, will eat animal food occasionally — especially when, in captivity, they are deprived of their usual food supplies. Far away from land the *Carinaria* and *Firola* pursue the floating acalephe, the *Janthina* varies its diet by occasionally swallowing smaller individuals of its own species (Coates); and the argonaut, with his relative, the *Spirula*, both carnivorous, are found on the “high seas,” in almost every quarter of the globe. The most active and rapacious of all are the calamaries and cuttles, who vindicate their high position in the naturalist’s “system,” by preying even on fishes, as well as lamellibranchs and crustaceans.

As the shell-fish are great eaters, so in their turn they afford food to many other animals; fulfilling the universal law of eating and being eaten. They furnish precious resources of alimentation to man. The cephalopods (*Octopus*, *Sepia*, *Loligo*) are captured for the market in the Mediterranean countries, especially in Italy), as well as in Japan and China; and dried cuttle-fish are regularly exported from China to San Francisco, California, where the Chinese inhabitants use them for soup.

Among the marine gastropods *Patella*, *Haliotis*, *Buccinum undatum*, *Littorina*, etc., are sent in quantities to the markets of London and Paris; *Murex* and *Turbo* are eaten in Italy; *Strombus gigas* and *Trochus pica* in the West Indies (Beau); *Strombus Luhuanus*, *Turbo chrysostomus*, *Trochus Niloticus*, *Patella testudinaria*, etc., at New Caledonia (Montrouzier); *Dolabella Teremidi*, at Tahiti (Rang); *Strombus tricornis*, *Murex Erythræus*, *Melongena paradisiaca*, at Suez (Vaillant); *Fusus colosseus*, *Rapana bezoar*, *Purpura luteostoma*, on the coast of China (Debeaux); *Turbo niger*, *Concholepas Peruvianus*, in Chili (d’Orbigny). A few fluviatile gastropods are eaten: *Navicella* and *Neritina* by the negroes of the Isle of France (Récluz); *Ampullaria effusa*, *Neritina punctulata*, by those of Guadeloupe, W. Indies (Beau); *Paludina* by the natives of Cambodia.

Among the terrestrial gastropods the *Helices* were most highly esteemed as a dainty dish by the ancient Romans, and they are still regularly sold in large quantities, living or cooked in the markets of France, Spain and Italy. I have seen cooked snails offered in the streets of London at one penny per plate. *Helix pomatia*, one of the largest of European snails, is considered still, as it was by the Romans, the best of the edible species, but a number of others are regularly brought to market. Colonies of snail-eating peoples have naturalized their delectable food in distant quarters of the earth; thus *Helix memoralis* is estab-

lished at Charleston, S. C.; *H. lactea* at Montevideo; *H. aspersa* in California, etc. The natives of New Caledonia eat quantities of the large bulimi (*Placostylus*) characteristic of that archipelago; in Guatemala the large *Helix Ghiesbreghti* is eaten.

The pelecypoda or bivalve shell-fish are consumed in such quantity as to rank with the principal kinds of animal food. The oyster trade has become enormous and is constantly growing. The best known edible species are *Ostrea edulis*, in Europe; *O. angulata*, on the west coasts of France and Portugal; *O. lamellosa*, in the Mediterranean; *O. borealis*, and *O. Virginica*, on the Atlantic coast of the United States; *O. parasitica*, in the West Indies; *O. tuberculata*, at the Cape of Good Hope; *O. cornucopiæ* at Suez, etc.

The sea-mussel (*Mytilus edulis*) is largely gathered by the inhabitants of the European coasts, and I have seen it for sale in many coast towns. It is sufficiently valuable to be cultivated carefully in parks on the west coast of France and the northern shores of Germany. The same species is abundant on the Atlantic coast of the United States, but does not appear to be much esteemed, and is rarely offered for sale.

But nearly all the marine bivalves are edible; among those most used, may be cited the species of *Pecten*, *Spondylus*, *Arca*, *Cardita*, *Cardium*, *Venus*, *Donax*, *Cytherea*, *Solen*, *Mya*, *Pholas* of European seas; *Venus Mercenaria*, *Mya arenaria*, *Mactra solidissima*—all called clams, *Solen ensis*, the razor-shell, and *Pecten irradians*, of the United States; *Lucina* and *Donax*, in the West Indies; *Avicula margaritifera*, *Cytherea Arabica*, at Suez (Vaillant); *Cytherea petechialis*, *Lucina Philippiana*, *Mactra veneriformis*, in China (Debeaux); *Mesodesma striata*, *Lucina tigrina* in New Caledonia (Montrouzier); *Tridacna mutica*, in the Caroline Islands, and *T. gigas*, at New Ireland (Quoy and Gaimard); *Mesodesma Chilensis* at Valparaiso (d'Orbigny).

Fresh-water bivalves are less sought for food on account of the insipidness of their flesh. The many species of *Unio* of the Western and Southern rivers of the United States are scarcely at all eaten; but in France the indigenous *Unionidæ* are collected in some of the poorer districts. *Anodonta edulis* is cultivated for food in the ditches of Song-Kiang-Fou, China, (Heude); *A. sempervirens* is eaten by the natives of Cambodia (Jullien); and the *Ætheria*, or fresh-water oyster, which forms its "banks" in the rivers of Africa, is consumed by the negroes.

The Kjökkenmöddings, or kitchen refuse-heaps, which have been found so abundantly on both shores of the United States, Brazil, Denmark, Scotland, New Zealand, Australia, etc., are mounds, sometimes hundreds of yards in length, and usually composed almost entirely of the shells of edible mollusks, mixed

with the bones of mammals, birds, fishes, the ashes of fire, broken pottery, and domestic implements made of stone or bone. They are the remains of pre-historic feasts; and some of these mounds are so great as to indicate that they were resorted to for centuries. The species of shells are usually those which now inhabit the neighboring sea, and which are still eaten.

Mollusks are gathered in great quantity for fishing-bait; thus the cuttle-fish is used in the cod-fishery, off Newfoundland; the *Patella* (limpet) and *Buccinum* (whelk) on the British, and the *Octopus* and *Cardium* on the French coasts. A large number of wild animals either habitually live on mollusks, or take them in default of other food; the rat and the raccoon seek for them when pressed by hunger; the musk-rat loves *Uniones* and the open valves, remains of his feasts, are often seen near American streams;* the South American otter and the crab-eating opossum constantly resort to salt marshes, and the sea, in order to prey on the mollusca. The walrus lives almost exclusively on *Mya arenaria* and *M. truncata*; some cetaceans destroy prodigious quantities of mollusks and are *par excellence* the squid-eaters or Teuthophages (Eschricht); thus in the stomach of divers Hyperoödon have been found more than two quarts of cephalopod beaks (Jacob), several hundred sepia beaks (Bylerly), finally, more than eighteen quarts of these beaks, and nothing else (Gray). Twenty-nine beaks were found in the first stomach of a grampus, and that of a globicephalus contained nothing else (Fischer). In the regions frequented by these cetaceans may be seen thousands of the bodies of *Sepia*, thrown to one side after the head has been bitten off and eaten (Lesson); these bodies are probably rejected on account of the cuttle-bone, which the whale does not appear to consider nutritious. Ambergris, an intestinal product of the cachelot, contains the beaks of cephalopods, which probably communicate to this substance its musky odor.

The *Balæna* is said by several authors to live habitually on the Pteropoda (*Limacina* and *Clio*), but it has been proven that banks of small crustaceans (*Cetochilus*) form its principal food.

Sea-fowl search for littoral species at every ebbing tide, whilst the ducks and herons destroy fresh-water mollusks, and many birds eat terrestrial snails. The Kagou (*Rhynochetus jubatus*) of New Caledonia lives on the large *Bulimi*, the shell of which it pierces with its beak (Marie). The Gorfous (*Eudytes chrysolepha*), which swims very well upon the ocean, even attacks the cephalopods, and the stomach of one of these birds was found to contain about twenty mandibles of *Ommastrephes* (Vélain).

* This animal is believed to bring the mollusk out of the water and place it where the heat of the sun kills it, causing the valves to open.

Reptiles furnish a few destroyers of mollusks. Thus the tortoises of our gardens eat snails, and it is common to put these animals in a cellar infested with slugs in order to exterminate them; the toad eats both snails and *Helices*; the frog and water-lizard eat the fresh-water snails; the *Pseudopus*, of our menageries, eats snails only.

In their own element, marine mollusks are perpetually devoured by fishes. The haddock is a "great conchologist;" and some rare northern shells (*Glycimeris*, *Buccinum*, *Neptunea*), have been rescued unbroken from the stomach of a cod. (One of them furnished thirty-five to forty shells of *Buccinum undatum*.) Hyndman has estimated at 35,000 the mass of a small bivalve shell (*Turtonia minuta*) found in the stomach of a mullet (Jeffreys). Some fishes break the most solid shells; thus the valves of a *Cyprina* cannot resist the teeth of the cat-fish (*Anarchichas lupus*). The Octopus, notwithstanding its intelligence, cunning and powers of defense, is very frequently the victim of the Conger Eel, which seizes it in its most secluded retreats.

The oyster-culturists at Arcachon (France) dread the ray, a fish which attacks young oysters. In one night, fourteen of these fishes destroyed more than 170,000 young oysters in a single parc. In the Oostanaula River, Georgia, the drum-fish (*Pogonias chromis*, L.) crushes the valves of *Unios* with its palatal armature in order to eat the soft parts.*

Articulated animals destroy but few shell-fish. Fischer has seen crabs break the shell of young oysters with their pincers; *Libinia canaliculata*, the common spider-crab of the American coast is very destructive to oyster-beds, and some others of our crabs have probably similar habits. *Carabus*, *Georus*, *Staphilinus*, *Cychrus* and *Sylpha*, among insects attack terrestrial gastropods. The larva of *Drillus Mauritianus* detaches with its mandibles the operculum of *Cyclostoma mamillare*, and undergoes metamorphosis within its shell, after having eaten the rightful proprietor (Lucas). Larval glow-worms also live on *Helices*, and will eat two or three before passing into the nymph state (Godard). *Cochleoctonus vorax* lays an egg in the body of different species of snails; when hatched, the larva feeds upon its host (Jeffreys). The species of *Perthostoma*, an American aquatic hemipterous insect, eat large quantities of *Limnæa*, *Physa* and *Planorbis*, which they hold with the fore-legs by folding between the thighs and tibiæ; even the larva of this insect, shortly after escaping from the egg, will seize and devour one of these mollusks with as much ease as if schooled in the process a long time (Leidy). Mollusks even fall a prey to animals much their inferiors in sagacity. Thus the star-fish swallows

* Bull. Ann. Mal. Belgique, xii, 23.

small bivalves entire (*Donax*, *Mactra*, *Cardium*), and dissolves the animal out of its shell; the digestive cavity of the Actinias nearly always contains gastropods (*Bulla*, *Nassa*, *Trochus*, *Rissoa*, etc).

A number of other animals live parasitic upon mollusks. There are several crustacean parasites of *Doris*; the lamelli-branchiates are frequently infested with the *Pinnotheres*; a little crab of this genus is frequently found enclosed in the valves of the American oyster; the marine mussel (*Mytilus*) often nourishes a similar guest; *Ostracotheres Tridacnæ* takes hold of the branchiæ of *Tridacna* (Rüppell), and a little brachyurous crustacean, of a brilliant blue color, is nearly always found attached to the raft of *Ianthina*.

Pulmoniferous gastropods are infested by little acarides. The *Philodromus limacum* lives in the pulmonary chamber of European limaces and snails; and a similar species, *Hypopus concolor*, Hald., is found abundantly upon American *Helices*. But the Vermes furnish the largest contingent of parasites on Mollusks: unfortunately for science, we scarcely know anything concerning the cycle of their migrations. The following example will serve to show the interest attending such researches: The sporocysts or germinative sacs of *Distoma retusum* produce, in the Limnæans, the Cercariæ, or tailed larva, without genital organs. These Cercariæ are encysted in the interior of neurop-terous larva. Finally they complete the cycle of their transformations in the frog, where under the form *Distoma* they acquire sexual organs. Several other forms, larval in aquatic mollusca, and perfect in frogs and aquatic birds, are known to science.

Aspidogaster conchicola lives in colonies in the pericardium of *Unio* and *Anodonta*, and *Cotylaspis insignis* occurs in the upper branchial cavity of the latter genus (Leidy). The *Paludina vivipara* of Europe nourishes no less than eight species of minute parasites. Prof. Haldeman, and others, have described several parasites upon American fresh-water mollusks; among them is *Anoplophrya vermicularis*, which Dr. Leidy observed in the intestine of *Paludina decisa*, sometimes so abundant as to distend the intestine.

Among terrestrial mollusks, *Succinea* lodges, in the interior of its tentacles, a sporocyst called *Leucochloridium paradoxum*, which is transformed in various birds into *Distoma macrostomum*. The tentacle thus occupied is swelled far beyond its usual size. Baudon states that the wagtail opens these tentacles for the purpose of eating the larva. Dujardin has seen several species of *Distoma* in the viscera of *Helix* and *Limax*.

The Trematodæ of marine mollusks are less known; they have been found in *Buccinum undatum* and *Littorina litorea*.

Nematoid worms are also parasitic in the Limaces. Some of the Hirudineæ attack shell-fish; *Malacobdella* lives upon *Mya*, *Venus*, *Cyprina*, *Cytherea*; *Clepsina*, *Aulastomum*, *Nephelis*, etc., attach themselves to the tissues of fresh-water mollusks. Dr. Leidy has recently described a larval *Distoma cornifrons*, found in the liver of *Donax fossor*, and which probably undergoes further development in some of the shore birds or fishes which eat the *Donax*; the same mollusk also harbors the infusorian *Trichodina pediculus*.

Means of Defense. In no class is the instinct of self-preservation stronger, nor the means of defense more adequate than in the mollusca; their shells seem expressly given to compensate for the slowness of their movements, and the dimness of their senses. The cuttle-fish escapes from attack by swimming backwards and clouding the water with an inky discharge; and the sea-hare (*Aplysia*) pours out, when irritated, a copious purple fluid, formerly held to be poisonous. The purple fluid of the *Murex*, *Purpura* and *Mitra*, the whitish liquid produced by the marginal pores of *Oncidiella*, and the mucous secretion of terrestrial snails are all probably protectory in character. The dorsal papillæ of *Æolis*, carry at their extremity an urticating apparatus, consisting of a capsule, opening by an orifice, and containing some cellules, in the interior of which is enrolled a simple or barbed filament; this apparatus is analogous to those of the actiniæ and many of the cœlenterata.

The prick of the lingual teeth of some mollusks is poisonous. Captain Belcher was thus bitten by a *Conus* which he was handling, and the slight wound was followed by a very painful swelling. *Conus marmoreus* is considered a dangerous animal in New Caledonia; and accidents caused by the teeth of *Conus textile* are rather numerous in the New Hebrides (Montrouzier). Quoy and Gaimard have remarked that the lingual teeth of Cones are hollow, and provided with a sort of fish-hook at their free extremity; they are supposed to be detachable; and this hypothesis appears to be confirmed by the presence of a contraction near the insertion of the tooth on the lingual plate (x, 5).

Lamellibranchs and a large number of gastropods escape their enemies by the resemblance of the color and surface of their shell to their surroundings. Thus *Patella* and many other genera, are ordinarily covered with *Balani* and marine growths; others are hid under Bryozoa and encrusting sea-weeds, *Serpulæ*, *Vermetidæ*, *Alcyonaria* and Sponges; *Xenophora* solders shells and coral to its shell, or covers it with small pieces of stone, so that it looks like a small heap of dead shells or pebbles; the Poulpe (*Octopus*) shelters himself under the carapaces of crabs, or covers himself with bivalve shells; *Lima* forms a retreat in a

nest of interlaced byssiferous filaments containing fragments of shells, nullipores, etc. (Jeffreys).

Mimicry or adaptive coloration in the mollusca has been but little studied. Cephalopods are known to change their color to resemble the ground upon which they rest; and some of the gastropods living upon marine growths vary their colors according to that of their habitation. *Lacuna*, on the North Atlantic Coast of the United States, has a shell tinted conformably to the different species of *Laminaria* upon which it is found; and a little red *Chiton* lives on rocks carpeted with *Algæ* of the same hue (Morse).

It must be confessed that the instincts of the shell-fish are of a low order, being almost limited to self-preservation, the escape from danger, and the choice of food. An instance of something like social feeling has been observed in a Roman snail (*Helix pomatia*), which, after escaping from a garden, returned to it in quest of a fellow-prisoner; but the accomplished naturalist who witnessed the circumstance hesitated to record a thing so unexampled. The limpet, too, we learn from the observations of Mr. George Roberts, of Lyme Regis, is fond of home, or at least possesses a knowledge of topography, and returns to the same roost after an excursion with each tide. Professor Forbes has immortalized the sagacity of the razor-fish, which submits to be salted in its hole, rather than expose itself to be caught, after finding that the enemy is lying in wait for it. On the other hand, Mr. Bowerbank has a curious example of "instinct at fault," in the fossil spine of a sea-urchin, which appears to have been drilled by a carnivorous gastropod.

Monstrosities. We have already spoken of the various abnormal growths of shells; the unrolling of the spire, the reversal of its direction, etc., and the displacement of the organs caused by this latter frequently-occurring variation: it remains to mention a few of the less frequently observed instances of monstrous growth in other parts of the animal than those affected by its shelly covering. Fischer has seen a *Submarginula* having two tentacles and two eyes on each side; and Bert records the case of a *Patella* in which those organs were doubled on one side only; bifid or forked tentacles are not rare among the *Limnæans*. The union of the long tentacles into a single one has been observed in *Limax* by Forbes and Hanley, and in *Vitrina* by l'Hôpital. Notwithstanding the coalescence of the tentacles, there were two eyes at the extremity. Double monsters have been frequently seen in the embryos of *Philine aperta*: they appear to be formed by the junction of two germs contained in the same shell.

Duration and Tenacity of Life. Not much is known respecting the individual duration of the shell-fish, though their length of

life must be very variable. Many of the aquatic species are annuals, fulfilling the cycle of their existence in a single year; whole races are entombed in the wintry tide of mud that grows from year to year in the beds of rivers, lakes and seas; thus, in the Wealden clay we find layer above layer of small river-snails, alternating with thin strata of sediment, the index of immeasurably distant years. Dredgers find that whilst the adults of some shell-fish can be taken at all seasons, others can be obtained late in the autumn or winter only; those caught in spring and summer being young or half-grown; and it is a common remark that *dead* shells (of some species) can be obtained of a larger size than any that we find alive, because they obtain their full growth at a season when our researches are suspended. Some species require part of two years for their full development: the young of the Doris and Eolis are born in the summer time, in the warm shallows, near the shore; on the approach of winter they retire to deeper water, and in the following spring return to the tidal rocks, attain their full growth early in the summer, and after spawning-time disappear.

The land snails are mostly biennial; hatched in the summer and autumn, they are half-grown by the winter time, and acquire their full growth in the following spring or summer. In confinement, a garden-snail will live for six or eight years; but in their natural state it is probable that a great many die in their second winter, for clusters of empty shells may be found, adhering to one another, under ivied walls, and in other sheltered situations; the animals having perished in their hibernation. Some of the spiral sea-shells live a great many years, and tell their age in a very plain and interesting manner, by the number of fringes (*varices*) on their whorls; the contour of the Ranella and Murex depends on the regular recurrence of these ornaments which occur after the same intervals in well-fed individuals, as in their less fortunate kindred. The Ammonites appear by their *varices*, or periodic mouths, to have lived and continued growing for many years.

Many of the bivalves, like the mussel and cockle, attain their full growth in a year, but various facts show that the adult size can be attained within a shorter period. Thus, a ship just careened and freshly bottomed left Marseilles, and in 48 days arrived at the River Gambia, where it remained 68 days, and in 86 days additional made the return voyage: which had lasted in all 202 days. Arrived at Marseilles, *Mytilus afer*, *Avicula Atlantica* and *Ostrea denticulata*, fully grown, were found attached to its bottom. These three species belong to the African fauna, and thus had acquired their adult size within five months after the earliest period at which, as young shells, they could have attached themselves (Petit). Fischer states that in

1863 he collected *Mytilus edulis*, four inches in length, from a buoy at Arcachon, which had been cleaned under his eyes a year previously: in this case the species had grown to nearly double the size which it normally attains within the same period in the mussel-banks of this locality.

The oyster continues enlarging its shell by annual "shoots," for four or five years, and then ceases to grow outwards; but very aged specimens may be found, especially in a fossil state, with shells an inch or two in thickness, and very heavy. The giant-clam (*Tridacna*), which attains so large a size that poets and sculptors have made it the cradle of the sea-goddess, must enjoy an unusual longevity; living in the sheltered lagoons of coral islands, and not discursive in its habits, the corals grow up around until it is often nearly buried by them; but although there seems to be no limit to its life (it may live a century for all that we know), yet the time will probably come when it will be overgrown by its neighbors, or choked with sediment.

The Meleagrina or pearl-oyster of Ceylon lives seven or eight years (Tennent).

The fresh-water mollusks of cold climates bury themselves during winter in the mud of ponds and rivers; and the land snails hide themselves in the ground, or beneath moss and dead leaves. In warm climates they become torpid during the hottest and driest part of the year. Among those which are inoperculated, the mantle at this time secretes a temporary door to the aperture, which is sometimes glutinous (*Orthalicus*), sometimes thin, like a lamina of isinglass, sometimes calcareous and thickened (*Helix pomatia*, *H. naticoides*, etc.). Occasionally, besides this calcareous plate, there are found one or several membranaceous epiphragms farther within the aperture.

Those genera and species which are most subject to this "summer sleep" are remarkable for their tenacity of life; and numerous instances have been recorded of their importation from distant countries in a living state. In June, 1850, a living pond-mussel was sent to Dr. Gray from Australia, which had been more than a year out of water. In December, 1874, Deshayes, in opening a box of *Anodonta*, collected eight months previously by the naturalists of the French expedition to Cambodia, found two individuals still living within their paper coverings. He has given to this species the name of "*Anodonta sempervirens*." The pond-snails (*Ampullariæ*) have been found alive in logs of mahogany from Honduras (Mr. Pickering); and M. Cailliaud carried some from Egypt to Paris packed in sawdust. Indeed, it is not easy to ascertain the limit of their endurance; for Mr. Laidlay having placed a number in a drawer for this purpose, found them alive after *five years*, although in the warm climate of Calcutta. The Cyclostomas, which are also

operculated, are well known to survive imprisonments of many months; but in the ordinary land-snails such cases are more remarkable. Some of the large tropical *Bulimi*, brought by Lieutenant Graves from Valparaiso, revived after being packed, some for thirteen, others for twenty months. In 1849, Mr. Pickering received from Mr. Wollaston a basket-full of Madeira snails (of twenty or thirty different species), three-fourths of which proved to be alive after several months' confinement, including a sea voyage. Mr. Wollaston has himself told us that specimens of two Madeira snails (*Helix papilio* and *tectiformis*) survived a fast and imprisonment in pill-boxes of two years and a half, and that a large number of the small *Helix turricula*, brought to England at the same time, were all living after having been enclosed in a dry bag for a year and a half.

Mr. Crosse has kept alive without nourishment, for more than two years, several specimens of *Helix signata* of Rome; and R. E. C. Stearns mentions a *Helix Veatchii* from Cerros Island, Lower California, which passed six years, from 1859 to 1865, without food.

This relaxation of the principal vital functions, will even, in certain cases influence reproduction. Gaskoin cites the case of a *Helix lactea*, obtained of a Mogador merchant in April, 1849, which had been kept for two years in a drawer, exposed to a dry atmosphere and dust. This isolated *Helix* laid thirty eggs in October, 1849, which attained their full size in less than a year. It could be objected to the opinion of Gaskoin, who considered this fact as proving an arrest of gestation, that parthenogenesis or fecundation *in situ*, is possible in the *Helices*, the genital gland including both male and female elements.

But the most interesting example of resuscitation occurred to a specimen of the Desert-snail, from Egypt, chronicled by Dr. Baird. This individual was fixed to a tablet in the British Museum on the 25th of March, 1846; and on the 7th of March, 1850, it was observed that he must have come out of his shell in the interval (as the paper had been discolored, apparently in his attempt to get away); but finding escape impossible, had again retired, closing his aperture with the usual glistening film; this led to his immersion in tepid water and marvelous recovery.

The small effect which extremes of temperature has upon mollusks assures their conservation. *Anodonta* and *Paludina* survive freezing, and will reproduce after being thawed (Joly). *Unio Requieni* lives in the thermal waters of Barbotan (France), the temperature of which is 86 degrees, in company with *Limnæa peregra* and *Physa acuta*. Analogous cases are recorded. Near Bona, Algeria, a *Hydrobia* lives in a thermal spring, the temperature of which is 108 degrees. *Planorbis Oregonensis*, Tryon,

was collected by the late W. M. Gabb in a thermal spring in the Pueblo Valley, Oregon, the temperature of the water being above blood heat. *Limnæa*, *Anodonta* and *Neritina*, are able to endure water slightly brackish; *Physa d'Orbignyana*, Lea, lives in the salt marshes at Monterey, California; and *Pholas*, *Teredo*, oysters, *Arca* and *Modiola* accommodate themselves to the fresh-water streams of Asia and Malaysia. On the other hand the numerous species of fresh-water Melanians of the Southern rivers of the United States, seem to be arrested in their distribution by the slightest admixture of sea-water, and do not approach the coast. A little *Limnæa* (*L. peregra*, var. *geisericola*) lives in the waters of the Geysers of Iceland (Mörch). The admixture of sulphurous and ferruginous elements in the streams does not seem to prevent the multiplication of some mollusks. *Cardium edule* has become extinct in the *Chotts* of Algiers and Tunis, on account of excess of brine, although a marine species; yet the fresh-water genera *Melania* and *Melanopsis* have been collected from waters surcharged with salt so as to be absolutely undrinkable, at the oasis of Ouargla, south of Algeria (Tournouër).

The permanency of the shell-bearing races is effectually provided for by their extreme fecundity; and though exposed to a hundred dangers in their early life, enough survive to re-people the land and sea abundantly. The mollusca exhibit the same instinctive care with insects and the higher animals in placing their eggs in situations where they will be safe from injury, or open to the influences of air and heat, or surrounded by the food which the young will require.

"If any one imbued with the spirit of Paley or Chateaubriand, should study these phenomena, he might discover more than the 'barren facts' which alone appear without significance to the unspiritual eye; he would see at every step fresh proofs of the wisdom and goodness of God, who thus manifests His greatness by displaying the same care for the maintenance of His feeblest creatures as for the well-being of man and the stability of the world."—WOODWARD.

Economic Uses of Shells. We have spoken of shell-fish as articles of food, but shells have other uses even to man; they are the toys of children, who hear in them the roaring of the sea; they are the pride of "collectors"—whose wealth is in a cone or "wentle-trap;" and they are the ornaments of barbarous tribes. The Friendly Islander wears the orange-cowry as a mark of chieftainship (Stutchbury), and it is somewhat rare to find a specimen in collections which has not been bored through the back for the purpose of suspending it; and the New Zealander polishes the *Elenchus* into an ornament more brilliant than the "pearl ear-drops" of classical or modern times (Clarke).

Other Oceanic tribes ornament their pirogues with the *Ovula*; and *O. angulosa* is so much esteemed by the natives of the New Hebrides that they will give in exchange for it a half ton of sandal-wood, worth four or five hundred francs (Montrouzier). The taste for shell ornaments has been exhibited by man since a very early period of his history, for the caverns of Europe contain both living and fossil species of shells, frequently pierced, and in intimate connection with undoubted remains of the stone age; the mound-builders of America likewise buried these with their dead along with other treasures, ornaments and implements. Leidy has recently found a *Conus*, a species inhabiting the west coast of Central America, among flint implements and numerous remains of living and extinct animals, in a cavern near Stroudsburg, Pennsylvania. The Troglodyte of Mentone, discovered by Rivière, the skeleton of which is preserved in the Museum of Paris, appears to have worn a coiffure ornamented with pierced shells of *Cyclonassa neritea*.

Shells serve as money in various parts of the world. In Africa, *Cypræa moneta*, the money-cowry has a fixed value in commercial transactions; *Dentalium pretiosum* and *Oliva biplicata* are standards of value among the Indians of the west coast of North America; *Littorina obesa* and *Nerita polita* are current in some of the Indo-Pacific Islands.

Fragments of the shells of *Venus mercenaria* (clam) were pierced and strung by the Indians of the Atlantic coast of the United States, forming their strings of Wampum or shell money; these were current among them for a considerable period after the advent of white settlers. Pieces of *Saxidomus* and *Haliotis* are similarly used by the natives of California (Stearns). The same usage prevails in Benguella. The shell of a terrestrial mollusk (*Achatina monetaria*) cut into circles, with an open centre is the monetary sign employed in commerce, and in payment of a part of the tribute. They are formed into chaplets called *Quirandas de dongo*, which serve also as ornaments for the ladies (Morelet). Even in the prehistoric grottoes of Europe have been collected pierced fragments of *Cardium edule*, which were probably used as "wampum" by the rude people who resorted to such localities.

One of the most beautiful substances in nature is the shell-opal, formed of the remains of the Ammonite. The forms and colors of shells (as of all other natural objects), answer some particular purpose, or obey some general law; but besides this, there is much that seems specially intended for our study, and calculated to call forth enlightened admiration. Thus the tints of many shells are concealed during life by a dull external coat, and the pearly halls of the Nautilus are seen by no other eyes than ours. Or descending to mere utility, how many tracts of

coast are destitute of limestone, but abound in shell-banks which may be burned into lime ; or in shell-sand, for the use of farmers.

The taste for collecting shells and competition among collectors have caused some of the rarer species to be valued at extraordinary prices, which usually tend to diminish as the formerly little-frequented regions which they inhabit become better explored. The extravagant rates that have been given for rare shells are less to be regretted, since they have induced voyagers to collect them. Mere shell-collecting, however, is no more scientific than pigeon-fancying, or the study of old china. For educational purposes the best shells are the *types* of genera, those which illustrate particular points of structure ; and, fortunately for students, excellent generic suites can be obtained for very reasonable prices. Not only have well-named private collections largely increased in number during late years, but almost every college museum includes what would formerly have been considered a large conchological cabinet. The three largest conchological collections in the world are those of the Academy of Natural Sciences of Philadelphia, the British Museum, and the Museum of Natural History at Paris. The first-named includes about 140,000 specimens, all mounted and labeled, contained in about 35,000 trays ; its geographical suites are the most extensive known. The British Museum collection is about half or less than half as large as that of the Philadelphia Academy, but contains many more specific types, inasmuch as it includes the famous Cumingian Collection. A large majority of these types are not good species ; nevertheless they have a value as evidence that their described distinctive characters are valueless.* The Paris collection is, perhaps, the smallest, but its

* "No one knew better than Mr. Cuming the value of a new name to his specimens, as shown by his enmity to any one who doubted the novelty of the species described. He would not allow me to see his collection for many years after his return from South America, because I had pointed out to him at one of the meetings of this society that some of the shells which Messrs. Sowerby and Broderip had described as new were well known species, and well figured by Chemnitz." "Since that period Mr. Cuming refused a well-known conchologist, who had previously described several shells from his cabinet, any further use of his collection, because he refused to admit that certain specimens which he sent to him to be described were new to science, or different from species already described. The system that Mr. Cuming adopted of selecting three specimens of each variety or species most alike, tended to prevent the number of nominal or presumed species from being observed during a casual examination of the collection, as it excluded those specimens which showed the transition from one variety to another, which occurs in any given species—more especially as the species were not arranged in the drawers so that the most allied of presumed species were near to each other, but, on the contrary, they * * * were often placed in distant parts of the series."—Dr. J. E. GRAY, *Zool Proc.*, 729, 1867.

arrangement is admirable; moreover it contains a host of species collected by the numerous French Exploring Expeditions—species very imperfectly represented elsewhere.

Some information concerning “fancy” prices paid for shells may be of interest. *Scalaria pretiosa*, which can now be had for one or two dollars, was worth \$100 in 1735 and \$200 in 1701. *Phasianella bulimoides*, which also brought \$100, can now be purchased at from one to two dollars, or even less. In 1865 a great English collection, that of Dennison, was sold by auction, in London, and some extravagant prices realized. *Cypræa guttata* brought \$200; *Cypræa princeps*, the same; *Conus gloria-maris*, also \$200; *Conus cervus*, nearly \$90; *Conus cedo-nulli* (not a very rare shell), \$90 and \$110; *Conus omaicus* (also not rare), \$60; *Voluta festiva*, \$80; *Oniscia Dennisoni*, \$90; *Pholadomya candida*, \$65 (several fine specimens in the Philadelphia Collection); *Carinaria vitrea* (which Montfort stated to be worth \$600) brought \$50. The very rare *Pleurotomaria Quoyana* brought in London, in 1872, \$125. In 1876 the Ræters van Lennep collection was sold, including: *Voluta Junonia*, \$50; *Mitra Belcheri*, \$40; *Spondylus regius*, \$36, etc. For this same *Spondylus regius* Professor Richard had previously paid several thousand francs. *Voluta Junonia* has always been considered a rare species, and dealers have obtained as much as forty pounds sterling for it. They still ask large prices for it, although a number of specimens are obtained yearly by dredging or otherwise, and they can generally be bought from first hands at from six dollars to twelve dollars each. *Cypræa umbilicata* has been sold for thirty pounds, and may now be had for one pound. The Boston Society of Natural History possesses an *Argonauta argo* or Paper Nautilus shell, which is said to have been purchased by the gentleman who presented it to that Society for \$500. It is a common species, and the only reason for the great valuation of this specimen, is that its diameter is about two or three inches greater than any other individual known to naturalists.

For scientific purposes common shells are quite as good as rare ones, and the price demanded for a single rarity will generally suffice for the purchase of many species of more frequent occurrence. Lovers of the beautiful are certainly justified in acquiring preferentially, fine specimens for their cabinets, but the too frequent custom of paying high prices for presumed novelties has led to much abuse in the description of new species. I cannot better illustrate this fact than by citing again from Dr. Gray's paper on the Cumingian Collection, published in the Zoological Proceedings, London, 1867:

“A very large number of species in the collection have been separated on very slight characters, or on the slightest variation of form, state, and color. This has greatly arisen from the

description and figuring of shells lately made known chiefly falling into the hands of dealers, * * * or of persons employed by dealers, who select for their purpose those who are ready to fall into their views and make as many new species as possible. * * * A shell with a new name is much more valuable in a pecuniary point of view than one with an old and well-known name. The value dealers attach to new names is proved by an incident that occurred to myself a few days ago, when a dealer offered me a new *Volute* for ten guineas. I said it was not new, only a slight variety of a well-known species. At length he admitted that he had nine specimens of the *Volute*, and ended by offering to present me with the best of the series if I would describe it as a new species. I am told that at length he found a person to fall into his views, and sold all his specimens at or above the price first mentioned."

GEOGRAPHICAL DISTRIBUTION OF THE MOLLUSCA.

Living beings are not distributed at hazard through the depths of the waters and over the surface of the earth, but each species occupies a determined area and has a distinct geographical distribution. In searching for the causes of this law, physical conditions have been first thought of; time, also, is one of the greatest factors, evidently; and the laws of variation or adaptability, as yet so little understood, will serve to cast much light on the problem: but after all these factors and all the deducible consequences are fully before us there is still the great question of origin to be considered; and for this we are forced to accept one of two pure hypotheses: either that centres of creation exist by God's will and independent of physical conditions, or that diverse beings, however isolated in distribution, are all the descendants of a common ancestral type, and have therefore probably been derived from a unique creation. The latter hypothesis is the most fashionable at present, because in this age man observes rather than marvels, and it is more satisfactory to the human mind to be able to account for things being as we find them than to refer their existence to the more or less immediate intervention of an unknown and unknowable power. Perhaps the development theory has done more to give us a truly philosophical view of nature than any other hypothesis has ever done, but there can be no doubt that many of its principal advocates have allowed their judgment to become dazzled by its very brilliancy, and in accepting as facts merely speculative propositions, have discovered an amount of credulity quite equal

to that of the most conservative of their opponents. I should write this book to little purpose, if I should not be able to indicate the identity of origin of many so-called distinct genera or species, and that in these cases, at least, physical causes have been amply sufficient first to produce and then to maintain diversity; but the proposition that therefore derivation must account for really important existing structural differences, receives little or no support from actual observation, so far as the mollusca are concerned.

The older authors, and those who still accept the idea that species are the result of the special intervention of Divine Will, have assigned to the genera and species of animals definite areas of distribution, and which are supposed to be more or less independent of physical causes. The occurrence of similar forms in distinct areas, they will not admit as conclusive of their common ancestry, but prefer to call them "representative species" and to marvel that separately created beings (therefore different species) should so closely resemble one another. I will here say plainly, as a result of many years' study of the geographical distribution of the mollusca, that defined limits to the so-called "Provinces" do not exist in nature except where these provinces have been fixed by physical causes alone; that whatever or wherever may have been the origin of the various genera or species, physical causes always sufficed to account for their subsequent distribution. I accept the existence of a species where theoretically it has no business to exist as proof that something is amiss with the theory. Geographical provinces of distribution having necessarily been determined through observation of the species composing them, when more extended observation modifies our knowledge, so should our boundaries vary. To illustrate: it was supposed that most of the shells inhabiting the Atlantic Coast of the United States, north of Cape Cod, were divided by it from those living southwards of that peninsula, and Cape Cod was accordingly made the boundary between two marine provinces; yet the multiplied researches of modern naturalists have shown and are showing that under like physical conditions neither northern nor southern species hesitate to cross the line which the closet-naturalist has forbidden them to cross. Deepsea dredgings also inform us that some Arctic mollusca are quite willing to extend southwards where the surface temperature would forbid their habitation, provided that at a greater depth they can secure climatal influences similar to the shore lines of the northern waters.

In most cases Provinces of Distribution or Areas of Assemblage of species *are* physically defined, in fact, although they have been so frequently somewhat arbitrarily constituted: yet we must carefully recognize the distinction between an assem-

blage or congeries of species as evidence of the existence of favoring conditions, and the inference that therefore those species are to be found nowhere else. It was thought that the conditions which prevented the Neptuneas of the boreal seas from extending southwards of Cape Cod, also would prevent the extension southwards of the equally boreal genus Buccinum, yet a typical species of the latter genus has far overstepped the boundary; and many species go wandering about the world like knights-errant, challenging the theorists—who invariably decline the issue on the ground that finding them where they have no business to be is sufficient proof that they are not themselves.

In order to constitute a distinct province it is considered necessary that at least *one-half* the species should be *peculiar*, a rule which applies equally to plants and animals. Some genera and subgenera are limited to each province, but the proportion is different in each class of animals and in plants.

Specific Areas. Species vary extremely in their range, some being limited to small areas, while others, more widely diffused, unite the local populations into fewer and larger groups. Those species which characterize particular regions are termed “endemic;” they mostly require peculiar circumstances, or possess small means of migrating. The others, sometimes called “sporadic,” possess great facilities for diffusion, like the lower orders of plants propagated by *spores*, and more easily meet with suitable conditions. The space over which a species is distributed is called a “centre,” or, more properly, a *specific area*. The areas of one-half the species are smaller (usually much smaller) than a single province.

In each specific area there is frequently one spot where individuals are more abundant than elsewhere; this has been called the “metropolis” of the species. Some species which appear to be nowhere common can be shown to have abounded formerly; and many probably seem rare only because their headquarters are at present unknown.—(FORBES.)

Specific Centres are the points at which the particular species are supposed to have been created, according to those who believe that each has originated from a common stock; these can only be known approximately in any case. The doctrine that each species originated from a single individual, or pair, created once only, and at one place, derives strong confirmation from the fact that so “many animals and plants are indigenous only in determinate spots, while a thousand others might have supported them as well.”

Boundaries of Natural History Provinces. The land provinces are separated by lofty mountains, deserts, seas, and climates; whilst the seas are divided by continents and influenced by the physical character of coast-lines, by climates and currents.

These "natural barriers," as they were called by Buffon, retard or altogether prevent the migrations of species in particular directions.

I am about to speak in detail of geographical provinces; but as I do not regard them from the same point of view as some of my predecessors, I have deemed it inadvisable to occupy as much space in the discussion as Woodward, for instance, has done. In fact, except where provinces are physically circumscribed, as an isolated island, for instance, their boundaries are more artificial than natural, and might, in many cases, be greatly changed without depriving them of that measure of exclusiveness which is held to constitute a distinct fauna. As to the distribution of the species, if we take a hundred species of the Panamic Province or Region, for instance, we shall find that we have a hundred areas of distribution, and no determinate specific centre. If, instead of the present divisions of Aleutian, Californian, Panamic and Peruvian Provinces, we should locate provinces of equal geographical extent *anywhere* on the coast, we should find as many species peculiar to them as to the former.

Granted that geographical provinces or regions do not fulfill the ideas which they were originally intended to convey, they are still useful (as many other partly artificial systems are useful), in recalling the character of the fauna of a given section of the world by means of a name. To subserve this purpose, it is advisable that the names and boundaries should not be subject to change, just as it is advisable not to change the name of a genus or species; I therefore, present the various provinces as they have been generally accepted, without reference to their varying values. Pelagic mollusks (cephalopods, pteropods, heteropods), have the most extended distribution, and, of course, cannot be considered properly as belonging to any particular faunal regions. The same may be remarked of deep-sea species, as the conditions under which they exist are altogether different from those which determine the distribution of littoral species. The latter only are taken into consideration in forming marine provinces.

Amongst the genera of marine shells there are some which have been considered particularly indicative of climate. From the Arctic list the following may be taken as examples of the shells of high latitudes; those marked * being found in the southern as well as in the northern hemisphere:—

Buccinum,	*Trichotropis,	*Rhynchonella,	*Astarte,
*Chrysodomus,	Velutina,	*Crenella	Cyprina,
*Trophon,	Lacuna,	Yoldia,	Glycimeris.
Admete,	*Margarita,		

The following have been thought peculiar to the warmer regions of the sea :

Nautilus,	Conus,	Columbella,	Perna,
Rostellaria,	Harpa,	Cypræa,	Vulsella,
Triton,	Oliva,	Nerita,	Tridacna,
Cancellaria,	Voluta,	Spondylus,	Crassatella,
Terebra,	Marginella,	Plicatula,	Sanguinolaria.

But it must not be inferred that these genera had always their present distribution. On the contrary, nearly the whole of them have existed in the British and American seas at no very remote geological period. *Rhynchonella* and *Astarte* were formerly "tropical shells;" and since the period of the English chalk-formation there have been living *Nautili* in the North Sea, and Cones and Olives in the "London basin."

The tropical and subtropical provinces might be naturally grouped in three principal divisions, viz., the Atlantic, the Indo-Pacific, and the West American—divisions which are bounded by meridians of longitude, not by parallels of latitude. The Arctic province is comparatively small and exceptional; and the three most southern Faunas of America, Africa, and Australia differ extremely, but not on account of climate.

If only a small extent of sea-coast is examined, the character of its mollusca will be found to depend very much upon the nature of the shore, the tides, depth, and local circumstances; but these peculiarities will disappear when the survey is extended to a region sufficiently large to include every ordinary variety of condition.

It has been stated that each fauna consists of a number of peculiar species, properly, more than half; and of a smaller number which are common to some other provinces. By ascertaining the direction of the tides and currents, and the circumstances under which the species occur, it may be possible to determine to which province these more widely diffused mollusca originally belonged. And when species occur both recent and fossil it is easy to perceive the direction in which their migrations have taken place. The fauna of the Mediterranean has been critically examined by Prof. Forbes and M. Philippi, with this result—that a large proportion of its population has migrated into it from the Atlantic, and a smaller number from the Red Sea, and that the supposed peculiar species are diminishing so rapidly with every new research in the Atlantic, that it can no longer rank as a province distinct from the Lusitanian.

MARINE PROVINCES.

There are eighteen Marine Provinces :

1, Arctic; 2, Boreal; 3, Celtic; 4, Lusitanian; 5, Aralo-Caspian; 6, West African; 7, South African; 8, Indo-Pacific;

9, Australo-Zealandic; 10, Japonic; 11, Aleutian; 12, Californian; 13, Panamic; 14, Peruvian; 15, Magellanic; 16, Patagonian; 17, Caribbean; 18, Transatlantic.

I. *Arctic Province.*

The North Polar Seas contain but one assemblage of Mollusca, whose Southern limit is formed by the Aleutian Islands in the Pacific, but in the North Atlantic is determined chiefly by the boundary of floating ice, descending as low as Newfoundland on the West, and thence rising rapidly to Iceland and the North Cape. The existence of the same marine animals in the Kamtchatka Sea and Baffin's Bay was long since held to prove at least a former Northwest passage; but the occurrence of recent sea-shells in banks far inland rendered it probable that even recent elevation of the land in Arctic America might have much reduced the passage. During the "Glacial period," this Arctic Sea, with the same fauna, extended over Britain; over Northern Europe, as far as the Alps and Carpathians; and over Siberia, and a considerable part of North America. The shells now living in the Arctic Seas, are found fossil in the deposits of "Northern Drift," over all these countries; and a few of the species yet linger within the bounds of the two next provinces, especially in tracts of unusual depth. The Arctic shells have often a thick epidermis and but little color; they occur in very great abundance, and are remarkably subject to variation of form; a circumstance attributed by Professor E. Forbes to the influence of the mixture of fresh water produced by the melting of great bodies of snow and ice.

II. *Boreal Province.*

The Boreal Province extends across the Atlantic from Nova Scotia and Massachusetts to Iceland, the Faroe and Shetland Islands, and along the coast of Norway from North Cape to the Naze; it includes Iceland except its northern coast. Its Southern American boundary is Cape Cod.

Of 289 Scandinavian shells catalogued by Dr. Lovén, 217, or 75 per cent. are common to Britain, and 137 range as far as the North coast of Spain.

The boreal shells of America are catalogued by Dr. Gould; from whose lists it appears that out of 270 sea-shells found on the coast of Massachusetts north of Cape Cod, more than half are common to Northern Europe.

Many of the species, it is believed, could only have extended their range so distantly by means of continuous lines of connecting coast, now no longer in existence.

This province is very poorly defined: a large portion of the

Arctic mollusca are or have been residents, whilst many of the species originating within its boundaries extend further southwards.

III. *Celtic Province.*

The Celtic Province, as described by Prof. E. Forbes, includes the British island coasts, Denmark, Sweden, and the coasts of the North Sea and Baltic. The fauna of this region (which includes the principal herring fisheries) is essentially Atlantic; many of the species are of ancient origin and occur fossil in the Pliocene.

Fischer admits that this province does not fulfill the zoological conditions, as it contains too large a proportion of boreal species, and very few peculiar to its region.

The British marine mollusca described by Forbes and Hanley amount to nearly 500 species.

Of this number two-thirds of the Nudibranchiata, and a few marine univalves, and bivalve shell-fish, are, at present, only known in British seas; but as most of these are minute or "critical" species, it is considered they will yet be met with elsewhere.

A few of the species belong to the Lusitanian province, whose northern limits include the Channel Islands, and just impinge upon the English coast. They appear mostly to have emigrated northwards after the glacial epoch, as they are not included in the Crag mollusca.

Of the Gastropoda 54 are common to the seas both north and south of Britain; 52 range farther south, but are not found northward of those islands; and 34 which find here their southern limit occur not only in Northern Europe, but most of them in Boreal America. Nearly half of the bivalves range both north and south of Britain; 40 extend southward only, and about as many more are found in Scandinavia, 27 of them being common to North America. (FORBES.)

According to Mr. M'Andrew's estimate in 1850, 406 British shell-bearing mollusca were then known, of which

217	or	53	per cent.	were common to	Scandinavia.
246	or	61	"	"	North of Spain.
227	or	56	"	"	S. Spain and Medit.
97	or	24	"	"	Canary Islands.

The wide expanse of the Baltic affords no shell-fish unknown to the coasts of Britain and Sweden. The water is brackish, becoming less salt northward, till only estuary shells are met with, and the Littorinæ and Limnæans are found living together, as in many of the British marshes.

IV. *Lusitanian Province.*

The Atlantic shores of France, Spain, Portugal, the Mediterranean, Black Sea, and N. W. Africa, as far as Cape Juby, form an important province, extending westward in the Atlantic as far as the Gulf-weed banks, so as to include Madeira, the Azores, and Canary Islands.

In the Atlantic portion of the province occur the following genera, not met with in the Celtic and Boreal seas, although two of them, *Mitra* and *Mesalia*, occur on the coast of Greenland:—

Argonauta.	Cancellaria.	Auricula.	—
Philonexis.	Sigaretus.	Pedipes.	Spondylus.
Chiroteuthis.	Crepidula.	Ringicula.	Avicula.
—	Mesalia.	Umbrella.	Solemya.
Conus.	Vermetus.	Glaucus.	Chama.
Pleurotoma.	Fossarus.	—	Crassatella.
Marginella.	Planaxis.	Carinaria.	Lithodomus.
Cymba.	Litiopa.	Firola.	Ungulina.
Mitra.	Truncatella.	Atlanta.	Galeomma.
Terebra.	Solarium.	Oxygyrus.	Cardita.
Columbella.	Bifrontia.	—	Cytherea.
Pisania.	Turbo.	Cleodora.	Petricola.
Dolium.	Monodonta.	Cuvieria.	Venerupis.
Cassis.	Haliotis.	Creseis.	Mesodesma.
Triton.	Gadinia.	—	Ervilia.
Ranella.	Siphonaria.	Megerlia.	Panopæa.

The great depth of the Gulf of Gascony has favored the introduction of some boreal mollusks; on the other hand, a few African genera extend into the Mediterranean.

France. Fischer catalogued in 1878, 569 species. Of these 336 are common to Great Britain and the Mediterranean; 91 are common to Great Britain, but not in the Mediterranean; 82 are common to the latter and not to the former; and 60 appear to be peculiar to the coast of France.

Spain and Portugal. These coasts are less known than any other part of the province, but the facilities for exploration are in some respects greater than in the Mediterranean, on account of the tides. Shell-fish are much in demand as an article of food, and the Lisbon market afforded to Mr. M'Andrew the first indication that the genus *Cymba* ranged so far north.

On the coasts of the Asturias and Galicia, especially in Vigo Bay, Mr. M'Andrew obtained, by dredging, 212 species, of a somewhat northern character, 50 per cent. of them being common to Norway, and 86 per cent. common to the south of Spain.

On the southern coast of the Peninsula 353 species were obtained, of which only 28 per cent. are common to Norway and 51 per cent. to Britain,

The identical species are chiefly amongst the shells dredged from a considerable depth (35–50 fathoms); the littoral species have a much more distinct aspect.

The shells of the coast of Mogador are generally identical with those of the Mediterranean and Southern Peninsula.

Canary Islands. The shells of the Canaries collected by MM. Webb and Berthelot, and described by M. d'Orbigny, amount to 124, to which Mr. M'Andrew has added above 170. Of the 300 species 17 per cent. are common to Norway, 32 per cent. to Britain, and 63 per cent. to the coasts of Spain and the Mediterranean. Two only are W. Indian shells, *Neritina viridis* and *Columbella cribraria*. Of the African shells found here, and not met with in more northern localities, the most remarkable are:—

Crassatella divaricata.	Ranella lævigata.	Cymba proboscidalis.
Cardium costatum.	Cassis flammea.	Conus betulinus.
Lucina Adansonii.	“ testiculus.	“ Prometheus.
Cerithium nodulosum.	Cymba Neptuni.	“ Guinaicus.
Murex saxatilis.	“ porcina.	“ papilionaceus.

Madeira. Mr. M'Andrew obtained 156 species at Madeira, of which 44 per cent. are British, 70 per cent. common to the Mediterranean, and 83 to the Canaries. Amongst the latter are the two W. Indian shells before mentioned, and the following African shells:—

Pedipes.	Mitra fusca.	Patella crenata.
Littorina striata.	“ zebrina.	“ guttata.
Solarium.	Marginella guancha.	“ Lowei.
Scalaria cochlea.	Cancellaria.	“ Candei.
Natica porcellana.	Monodonta Bertheloti.	Pecten corallinoides.

Azores. Amongst the littoral shells which range to the Azores, are Pedipes, *Littorina striata*, *Mitra fusca*, and *Ervilia castanea*; the other species obtained there are Lusitanian. (M'ANDREW).

The Mediterranean is the richest conchological fauna of temperate seas. In its western part it is mostly identical with that of the adjacent Atlantic coasts; the number of species diminishes eastward, although reinforced by a considerable number of new forms as yet only known in the Mediterranean; and three accessions of a different character, from the Red Sea. The total number of species is 1183, according to Monterosato and Fischer.

Cephalopoda, 53	Scaphopoda, 15	Lamellibranchiata, 302
Pteropoda, 19	Gastropoda, 782	Brachiopoda, 12

This enumeration includes the deep-sea dredgings of the Porcupine Expedition.

The Mediterranean fauna appears to be perfectly homogeneous; but a few African forms enter the Straits of Gibraltar, and are found on the adjacent coasts of Spain and Algiers. The most peculiar of these species is the large *Cymbium olla*, belonging to the family Volutidæ.

In the Bay of Cadiz, just without the Strait of Gibraltar lives the *Halia priamus*, the only representative of its genus. Its position in the system has been often changed, and it is only within late years that the animal has been obtained and its relationships understood. It is extinct in the Mediterranean, but fossil in the pliocene of the North of Italy. *Ungulina rubra*, of Senegal, has likewise been collected at Cadiz. *Strombus bubonius* of Senegal is found fossilized in the latest deposits of the newer pliocene.

The study of the miocene and pliocene tertiary fauna of the Mediterranean Countries shows that this Sea has received accessions belonging to the Indian Ocean, West Africa and North Europe. These tertiary fossils appear to indicate a much warmer sea, in which Polyps lived. Consequent upon its refrigeration and the interruption of the communication with the Indian Ocean, a number of these genera became extinct at the commencement of the pliocene epoch, although a few representatives of a more tropical fauna still survive. The following may be cited:

(*A*, African; *O*, Indian Ocean).

Umbrella, O.	Fasciolaria, A.	Mesalia, A.
Marginella, A.	Cancellaria, A.	Clavagella, O.
Cymbium, A.	Pedicularia, O.	Cardita, A. O.
Clanculus, A. O.	Sigaretus, A.	Chama, A. O.
Xenophora, A. O.	Siliquaria, A.	Spondylus, A. O.
Typhis, A. O.		

Finally the Mediterranean genera *Crepidula*, *Smaragdia*, *Dolium*, *Rissoina*, *Solemya*, *Thecidium*, are identical with American forms belonging to the Transatlantic and Caribbean Provinces.

Black Sea. In the northern part a few Aralo-Caspian shells are found, otherwise the Black Sea only differs from the Mediterranean in the paucity of its species; Dr. Middendorff enumerates 68 only. The water is less salt, and there is no tide, but a current flows constantly through the Dardanelles to the Mediterranean.

Gulf-weed Banks. The few species collected are principally pelagic, consisting of nudibranchiates, *Litiopa*, etc. Two species of Patellidæ are the only mollusks in common with Europe and there is no good reason why this fauna should be included in the Lusitanian Province.

V. *Aralo-Caspian Province.*

The only inland salt-seas that contain peculiar shell-fish are the Aral and Caspian. The shells chiefly consist of a remarkable group of Cockles (*Cardium*), which burrow in the mud. No explorations have been made with the dredge, but other species, probably still existing in these seas, have been found in the beds of horizontal limestone which form their banks and extend in all directions far over the *steppes*. This limestone is of brackish-water origin, being sometimes composed of myriads of *Cyclades*, or the shells of *Dreissena* and *Cardium*, as in the islets near Astrakhan. It is believed to indicate the former existence of a great inland sea, of which the Aral and Caspian are remnants, but which was larger than the present Mediterranean at an age previous to that of the Mammoth and Siberian Rhinoceros. The present level of the Caspian is 83 feet below that of the Black Sea; that of the Aral has been stated to be 117 feet higher than the Caspian, but is probably not very different; their waters are only brackish, and in some parts drinkable. The steppe limestone rises to a level of 200–300 feet above the Caspian; it spreads eastward to the mountains of the Hindoo Kush and Chinese Tartary, southward over Daghestan and the low region E. of Tiflis, and westward to the northern shores of the Black Sea. The extent to which it has been traced is represented by oblique lines on the map. Some of the Caspian shells still exist in the Sea of Azof and the estuaries of the Dnieper and Dniester.

Few other inland bodies of brackish water are known to have peculiar shells; those of the modern deposits, in Mesopotamia (at Sinkra and Warka), collected by Mr. W. K. Loftus, are species still abounding in the Persian Gulf. All the living shells of this Province are of estuary rather than marine character, the so-called Rissoa being a *Hydrobia*, and the shell described by H. Adams as *Velutina Caspiensis*, a *Limnæa Gebleri*, Midd.

VI. *West African Province.*

The tropical coast of Western Africa is rich in conchological treasures, and far from being wholly explored. St. Helena and Ascension Island are included. About 300 species have been obtained on the coast, and 150 species, mostly identical at the Cape Verd Islands. The most characteristic genera are *Pleurotoma*, *Oliva*, *Marginella*, *Cymbium*, *Terebra*, *Pusionella*, *Tympanotomus*, *Mesalia*, *Ungulina*, *Felania*, *Tugonia*, *Talona*, *Tellina*. There are 40 species of *Marginella*, 36 of *Pleurotoma*, 20 of *Tellina*. Quite a number of the species cross the Atlantic, recurring upon the opposite Brazilian and West Indian coasts.

VII. *South African Province.*

The fauna of South Africa, beyond the tropic, possesses few characters in common with that of the western coast, and is

more like the Indian Ocean fauna, as might be expected from the direction of the currents. But, together with these it has a large assemblage of marine animals found nowhere else, and the "Cape of Storms" forms a barrier between the populations of the two great oceans, scarcely less complete than the far-projecting promontory of South America. The coast is generally rocky, and there are no coral-reefs; accumulations of sand are frequent, and sometimes very extensive, like the Agulhas Bank. The few deep-sea shells which have been obtained off these banks possess considerable interest, but explorations in boats are said to be difficult, and often impossible on account of the surf. Shells from the Cape are too frequently dead and water-worn specimens picked up on the beach. The shell-fish of South Africa have been collected and described by Quoy and Gaimard, Owen Stanley, Hinds, A. Adams, and especially by Dr. Krauss, who has published a very complete monograph. Of 400 sea-shells recorded in this work, above 200 are peculiar, and most of these belong to a few littoral genera. Only 11 species are common to the coast of Senegal, whilst 18 are found in the Red Sea; 15 species are said to be found in Europe; all the others, not peculiar, exist on the E. coast of Africa. The following are remarkably developed: Chiton, 16 species; Patella, 20 species; Fissurella, 10 species; Trochus, 22 species; Phasianella, 6 species; Cypræa, 22 species.

The following are stated to be common to the Cape and European seas:

Saxicava (arctica?) Greenland,	Arca lactea, Medit.
Medit.	Chama gryphoides, Medit. Red
Tellina fabula, Brit. Medit.	Sea.
Lucina lactea, Medit. Red Sea.	Pecten pusio, Brit.
" fragilis, Medit.	_____
Venus verrucosa, W. Indies?	Diphyllidia (lineata?) N. Brit.
Brit. Senegal, Canaries, Red	Medit.
Sea, Australia?	Eulima nitida, Medit.
Tapes pullastra, North Sea.	Nassa marginulata.
" geographica, Medit.	Argonauta argo, Medit.

At the islands of St. Paul and Amsterdam, situated midway between the Cape and Australia, Velain collected 60 species, 46 of which he described as new.

VIII. Indo-Pacific Province.

This is by far the most extensive area over which similar shell-fish and other marine animals are distributed. It extends from E. Australia to S. Japan, and from the Red Sea and east coast of Africa to Easter Island in the Pacific, embracing three-fifths of the circumference of the globe and 45° of latitude.

This great region might, indeed, be subdivided into a number of smaller provinces, each having a particular association of species and some peculiar shells, such as the Red Sea, the Persian Gulf, Madagascar, etc.; but a considerable number of species are found throughout the province, and their general character is the same. Mr. Cuming obtained more than 100 species of shells from the eastern coast of Africa, identical with those collected by himself at the Philippines, and in the eastern coral islands of the Pacific. This is pre-eminently the region of coral reefs, and of such shell-fish as affect their shelter. The Philippine Islands have afforded the greatest variety, but their apparent superiority is due, in a measure, to the researches of Mr. Cuming; no other portion of the province having been so thoroughly explored. He collected 2500 species of sea shells at the Philippines, and estimates the total number at 1000 more. The genera most developed are *Conus*, 120 species; *Pleurotoma*, 100; *Mitra*, 250; *Columbella*, 40; *Cypræa*, 50; *Natica*, 50; *Chiton*, 30; *Tellina*, 50. No catalogue of the marine shells of the Province has been published, but they are believed to amount to between 5000 and 6000 species.

Amongst the genera most characteristic of the Indo-Pacific, those marked (*) are wholly wanting on the coasts of the Atlantic, but half of them occur fossil in the older tertiaries of Europe. Those marked (†) are also found on the west coast of America.

*Nautilus.	*Magilus.	Stomatella.	Hemicardium.
*Pteroceras.	*Melo.	Gena.	*Cypricardia.
*Rimella.	†Mitra.	*Broderipia.	*Cardilia.
*Rostellaria.	*Cylindra.	*Rimula.	†*Verticordia.
*Seraphs.	*Imbricaria.	*Neritopsis.	*Pythina.
†Conus.	Ovulum.	*Scutellina.	Circe.
†Pleurotoma.	†*Pyrula.	*Linteria.	*Clementia.
*Cithara.	*Monoptygma.	*Dolabella.	*Glaucomya.
†*Clavella.	Phorus.	*Hemipecten.	*Meröe.
*Turbinella(typ).	Siliquaria.	*Placuna.	Anatinella.
Cyllene.	*Quoyia.	*Malleus.	Cultellus.
Eburna.	*Tectaria.	*Vulsella.	*Anatina.
†Phos.	†Imperator.	*Pedum.	*Chæna.
Dolium.	Monodonta.	†*Septifer.	*Aspergillum.
†Harpa.	Delphinula.	*Cucullæa.	*Jouannetia.
*Ancillaria.	†Liotia.	*Hippopus.	†*Lingula.
*Ricinula.	*Stomatia.	*Tridacna.	†Discina.

The strictly littoral species vary on each great line of coast: for example, *Littorina intermedia* and *Tectaria pagodus* occur on the east coast of Africa; *Littorina conica* and *melanostoma*, in the Bay of Bengal; *Littorina sinensis* and *castanea*, and

Haliotis venusta, on the coast of China; *Littorina scabra* and *H. squamata*, in N. Australia; *H. asinina*, New Guinea; and *L. picta*, at the Sandwich Islands.

Red Sea (Erythræan). Of the 818 mollusca of the Red Sea, collected by MacAndrew at Suez, three only are common to the Mediterranean Sea.*

The genera wanting in the Mediterranean, but existing in the Red Sea, show most strikingly their diversity of character, and the affinity of the latter to the Indian fauna.

Pteroceras.	Ancillaria.	Siphonaria.	Limopsis.
Strombus, 8 sp.	Harpa.	Placuna.	Tridacna.
Rostellaria.	Ricinula.	Plicatula.	Crassatella.
Turbinella.	Magillus.	Pedum.	Trigona.
Terebra.	Pyramidella.	Malleus.	Sanguinolaria.
Eburna.	Parmophorus.	Vulsella.	Anatina.
Oliva.	Nerita.	Perna.	Aspergillum.

Other genera become abundant, such as *Conus*, of which there are 19 species in the Red Sea, *Cyprea* 16, *Mitra* 10, *Cerithium* 17, *Pinna* 10, *Chama* 6, *Circe* 10.

Persian Gulf. The marine zoology of the Persian Gulf and adjoining coast has not been yet explored. 92 species of shells were picked up on the beach at Kurrachee by Major Baker, with many others evidently new, but not in a satisfactory state for description.

Madagascar. Collections of marine shells have been made at Madagascar and the Mascarene Islands by Sganzin, and at the Seychelles by Dufo. The number obtained at the latter place was 263, of which 220 were univalves. Two of the univalves, viz., *Dolium galea* and *Cypræa helvola*, and two of the bivalves, are found in the Mediterranean.

IX. Australo-Zealandic Province.

Most remote from the Celtic seas, this province is also most unlike them in its fauna, containing many genera wholly unknown in Europe, either living or fossil, and some which occur fossil in rocks of a remote period. The province includes New Zealand, Tasmania, and extra-tropical Australia, from Sandy Cape, on the east, to the Swan River.

Of the following genera some are peculiar, others attain here their greatest development:—

* Woodward is in error in crediting the statement that 73 out of 375 species collected in the Red Sea, by Ehrenberg and Hemprich are Mediterranean species. Fischer has shown that these 73 species are exclusively Mediterranean forms and were probably collected on the Syrian coast or at Alexandria.

Pinnoctopus.	Macgillivraia.	Cypricardia.	Imperator.
Struthiolaria.	Amphibola.	Mesodesma.	Monoptygma.
Phasianella.	Trigonia.	Terebratella.	Siphonaria.
Elenchus.	Chamostrea.	Spirula.	Pandora.
Bankivia.	Myadora.	Oliva.	Anatinella.
Rotella.	Myochama.	Conus.	Clavagella.
Macroschisma.	Crassatella.	Voluta.	Placunomia.
Parmophorus.	Cardita.	Terebra.	Waldheimia.
Risella.	Circe.	Fasciolaria.	Crania.

Some of the genera of this province are only met with elsewhere at a considerable distance:—

Solenella—Chili.	Solemya—Medit.
Panopæa—Japan.	Rhynchonella—Arctic seas.
Bankivia—Cape.	Trophon—Fuegia; Arctic seas.
Kraussia—Cape.	Assimineia—India; Brit.

Amongst the littoral shells of South Australia are *Haliotis elegans*, *H. rubicunda*, and *Littorina rugosa*. *Haliotis iris* and *Littorina squalida* are found on the shores of N. Zealand; and *Cypræovula umbilicata* in Tasmania.

The New Zealand fauna includes about 400 marine species, of which about 50 species are common to S. Australia and Tasmania.

The Auckland Islands contain a number of New Zealand species, together with many Antarctic shells.

X. Japonic Province.

The Japanese Islands, the coast of Mantchuria and part of Corea represent the Japonic province. Our knowledge of its marine fauna has of late years received several valuable accessions. Of 429 species known in 1875, 145 or about one-third are peculiar to the Japanese Archipelago; 28 are common to the coast of Mantchuria, which presents a more Arctic character; 185 or about three-sevenths are common to China and the Philippines: 165 or about two-fifths, principally from the southern parts, belong to the Indo-Pacific fauna.

A number of species are common to the West Coast of America. The following have been cited. They may not all be correctly identified, but on the other hand the list could be readily made much longer:

<i>Siphonalia Kelletti.</i>	<i>Lutraria Nuttalli.</i>
<i>Triton Oregonensis.</i>	<i>Diplodonta orbella.</i>
<i>Nassa festiva.</i>	<i>Tellina nasuta.</i>
<i>Oliva anazora.</i>	“ <i>secta.</i>
<i>Solarium quadriceps.</i>	“ <i>inquinata.</i>
<i>Haliotis gigantea.</i>	<i>Cardium Californiense.</i>
<i>Crepidula aculeata.</i>	<i>Mytilus giganteus.</i>
<i>Cytherea petechialis.</i>	

The presence of the same genera gives a very similar aspect to the West American and Japonic faunas; especially the development of special forms, such as *Saxidomus*, *Siphonalia*, *Chlorostoma*, etc. A few circumpolar species occur in Japan, several of them being common to the Boreal province on the Atlantic coast of the United States, and to Great Britain. Among them are:

<i>Saxicava arctica.</i>	<i>Lasæa rubra.</i>	<i>Cardita borealis.</i>
<i>Mya arenaria.</i>	<i>Crenella faba.</i>	<i>Puncturella Noachina.</i>
<i>Modiola modiolus.</i>	<i>Nucula tenuis.</i>	

To complete the story of the intermixture of species, the following Mediterranean forms are also encountered:

<i>Triton olearius.</i>	<i>Turbo sanguineus</i> (var.).
<i>Lima squamosa.</i>	<i>Lithodomus caudigerus.</i>

XI. Aleutian Province.

The species of the Boreal province are well represented on the northern coasts of the Pacific; in addition to which there are many Californian and Japanese forms.

The influence of the Asiatic coast-current is shown in the presence of two species of *Haliotis*, whilst affinity with the fauna of W. America is strongly indicated by the occurrence of *Patella* (*Scurria*), three species of *Crepidula*, two of *Fissurella*, and species of *Bullia*, *Placumonia*, *Cardita*, *Saxidomus*, and *Petricola*, which are more abundant, and range farther north than their allies in the Atlantic.

The proportion of peculiar species in this Province is already surprisingly small, and is becoming smaller: it has but little claim to rank as a distinct fauna.

Provinces on the Western Coast of America.

The mollusca of the Western coast of America are equally distinct from those of the Atlantic and those inhabiting the central parts of the Pacific, but by no means so peculiar as Woodward supposed. I quote him to show how prepossessions will mislead naturalists:

“Mr. Darwin states in his Journal (p. 391) that ‘not one single sea-shell is known to be common to the Islands of the Pacific and to the west coast of America,’ and he adds that ‘after the comparison by Messrs. Cuming and Hinds of about 2000 shells from the Eastern and Western coasts of America, only one single shell was found in common, namely the *Purpura patula*, which inhabits the West Indies, the coast of Panama, and the Galapagos.’ Even this single identification has since been doubted. Mr. Cuming, who resided many years at Valparaiso, did not discover any West India specimens on that coast, and

M. d'Orbigny makes the same observation. On the other hand M. Mörch, of Copenhagen, says he has received *Tellina operculata* and *Macra alata* from the west coast and also from Brazil; and M. Deshayes gives the following extraordinary ranges in his 'Catalogue of *Veneridæ* in the British Museum':—

Artemis angulosa, Philippines—Chili.

Cytherea umbonella, Red Sea—Brazil.

“ *maculata*, W. Indies—Philippines, Sandwich.

“ *circinata*, W. Indies—West coast America.

In these instances there is doubtless some mistake, either about the locality or the shell. As regards the last, Mr. Carrick Moore has shown that the error has arisen from confounding the *Cytherea alternata* of Broderip with *C. circinata* of Born. M. d'Orbigny collected 628 species on the coast of S. America—180 from the eastern side, and 447 from the Pacific coast, besides the *Siphonaria Lessonii* which ranges from Valparaiso in Chili to Maldonado on the coast of Uruguay. These shells belong to 110 genera, of which 55 are common to both coasts, while 34 are peculiar to the Pacific, and 21 to the Atlantic side of S. America; an extraordinary amount of diversity, attributable partly to the different character of the two coasts—the eastern low, sandy or muddy; the western rocky, with deep water near the shore.

“ The comparison of the shells of Eastern and Western America is of considerable interest to geologists; for if it is true that any number of living species are common to the Pacific and Atlantic shores, it becomes probable that some portion of the Isthmus of Darien has been submerged *since* the Eocene Tertiary period. Any opening in this barrier would allow the Equatorial current to pass through into the Pacific—there would be no more Gulf stream—and the climate of Britain might, from this cause alone, become like that of Newfoundland at the present day.

“ Although geological researches seem to show that not only the Isthmus of Darien, but even the Rocky Mountains, were sufficiently submerged during the Miocene Epoch to allow of the free intermingling of the waters of the Atlantic and Pacific, yet the special temperate molluscan fauna of E. and W. America are very dissimilar. There are no grounds for believing a single species to be identical. There are, however, a large number of species (upwards of 50) living on both sides of the *northern* portion of the continent, and the majority of these exist in the British seas.”

The molluscan fauna of the Panamic and Carribbean Provinces contain very many species in common; these were, for a long period, distinguished as “representative” species, but the con-

tinual occurrence of additional common forms as our knowledge of the two faunas has increased, has finally entirely broken down the dogmatic theory so long held in common by Darwin, Cuming, Hinds, d'Orbigny, Adams, Gould, etc.; finally, the researches of Gabb, in San Domingo and Central America have brought to light in the tertiaries of the Caribbean area a number of species only found living in the Panamic Province. Not only does the Panamic Province hold many species in common with the Carribbean, but some of these are distributed over extensive areas on the West Coast, extending into the Californian and Chilian Provinces.

Woodward's assertion of the distinctness of the Polynesian and West American faunas is also much modified by recent investigations, which show many of the species of Panama to occur at the Galapagos, and quite a number of them to inhabit the Polynesian coasts, even as far as the Philippine Islands and Australia.

XII. *Californian Province.*

This extends from the Straits of Fuca on the north to Cape San Lucas, the southern extremity of the peninsula of Lower California, on the south: it does not include the Gulf of California, which possesses a more tropical fauna, belonging to the Panamic Province. A few circumpolar species extend to Vancouver Island and the coast of Oregon, and of course the Aleutian fauna is well represented in the northern part of the Province; on the other hand the shores of Lower California contain a considerable intermixture of Panamic shells. Still, the Californian mollusca as a whole form a tolerably distinct assemblage of species, widely differing from those of the corresponding East Coast of America, and, although containing many tropical and semitropical forms, sufficiently distinct from the Panamic fauna.

Over five hundred species have been recorded. The most remarkable feature of the Province is the enormous development of the Chitonidæ, Patellidæ, Haliotidæ, Trochidæ, etc.

XIII. *Panamic Province.*

The Western coast of America, from the Gulf of California to Payta in Peru, forms one of the largest and most distinct provinces. The total number of marine shells known belonging to this province was, a few years since, 1341. Amongst these are included 27 Chitonidæ, 13 Acmaeidæ, 18 Fissurellidæ, 64 Trochidæ, 28 Calyptræidæ, 69 Pyramidellidæ, 59 Buccinidæ, and 90 Muricidæ. The Gulf of California, together with the adjacent coast as far as Mazatlan and St. Blas, has yielded 768 shells (502 univalves and 266 bivalves), of which 439 also occur.

in the Gulf of Panama, while 117 extend into S. America; 635 species are known from the Gulf of Panama; of these, 266 are peculiar to the district, and 163 also occur in S. America. The fauna of the Panamic province is remarkably distinct from the other W. American provinces, and especially the Caribbæan. At one time it was thought that it did not possess a single species identical with any occurring in the West Indies or the east side of America. Dr. P. Carpenter, however, has shown that 35 marine shells (15 univalves and 20 bivalves) occur on both sides of the Isthmus of Darien, and this number has been lately considerably increased.

A few of the species even extend as far as W. Africa, according to Dr. Carpenter; he mentions 15, and among them the following: *Crepidula unguiformis*, *C. aculeata*, *Hipponyx antiquatus*, *Bankivia varians*, *Natica maroccana*, *Marginella cœrulescens*, *Nitidella guttata*. Five species are common to Mazatlan and the British coasts, viz., *Kellia suborbicularis*, *Lasea rubra*, *Saxicava arctica*, *Cytherea Dione*, *Hydrobia ulvæ*. Woodward says: "Still more remarkable is the absence of resemblance between the species of Panama and those of the Indo-Pacific area, there being only seven forms common to the two. Thus, *Cytherea petichialis* occurs in Japan; *Nassa acuta*, in Australia; and *Oliva Duclosii*, *Natica maroccana*, *Nitidella cribraria*, *Hipponyx barbatus*, *H. Grayanus*, are scattered over the Pacific ocean." The number of common species in the two Provinces is now known to be very much larger.

The river openings of this coast are bordered by mangroves, amongst which are found Potamides, Arcas, Cyrenas, Potamomyas, Auriculas, and Purpuras, whilst Littorinæ climb the trees and are found upon their leaves. The ordinary tide at Panama amounts to 16 or 20 feet, the extreme to 28 feet, so that once a fortnight a lower zone of beach may be examined and other shells collected. The beach is of fine sand, with reefs of rocks in the bay.

Galapagos Islands. Out of 111 sea-shells collected here by Mr. Cuming, 43 are unknown elsewhere; 25 occur in Mazatlan, 22 in Central America, 38 in Panama, but only 11 in South America.

XIV. Peruvian Province.

The coast of Peru and Chili, from Callao to Valparaiso, affords a large and characteristic assemblage of shells, of which only a small part have been catalogued, although the district has been well-explored, especially by d'Orbigny, Cuming and Philippi. M. d'Orbigny collected 160 species, one-half of which are common to Peru and Chili, whilst only one species (*Siphonaria Lessonii*) found at Callao was also met with at Payta, a little beyond the boundary of the region. Mr. Cuming obtained 222 species on

the coast of Peru, and 172 in Chili. Hupé has described 201 species in Gay's work on Chili. The island of Juan Fernandez is included within this province.

The shells of this region are remarkable for melanism. Chiton, Fissurella, Concholepas, Monoceras, Mytilus are predominant, and represented by large and fine species.

D'Orbigny in comparing the Peruvian fauna with those of Brazil, the Argentine Republic and Northern Patagonia mentions the remarkable fact that of 628 marine species, one only (*Siphonaria Lessonii*) lives on both shores of South America. A cold ocean current flows northwards on the West Coast of South America, and has doubtless greatly influenced the distribution of the mollusca.

XV. *Magellanic or Antarctic Province.*

This region includes the coasts of Tierra del Fuego, the Falkland Islands (Maloinas), and the mainland of South America, from P. Melo, on the east coast, to Concepcion, on the west. Fischer has very properly added to this Province Kerguelen's and neighboring islands, intermediate geographically between America and New Zealand, but the mollusks of which are principally American. It is described by M. d'Orbigny and Mr. Darwin (Journal, p. 177 *et seq.*). Philippi also has given attention to it: he assigns 88 species to the district near the Straits of Magellan. Only 15 species are known from the Maloinas, and 11 of these have not been met with elsewhere. The southern and western coasts are amongst the wildest and stormiest in the world; glaciers in many places descend into the sea, and the passage round Cape Horn has often to be made amidst icebergs floating from the south polar continent. The greatest tides in the straits amount to 50 feet. "In Tierra del Fuego the giant sea-weed (*Macrocystis pyrifera*) grows on every rock from low-water mark to 45 fathoms, both on the outer coast and within the channels; it not only reaches up to the surface, but spreads over many fathoms and shelters multitudes of marine animals, including beautiful compound Ascidians, various patelliform shells, Trochi, naked mollusca, cuttle-fish, and attached bivalves. The rocks at low water, also abound with shell-fish which are very different in their character from those of corresponding northern latitudes, and even when the genera are identical the species are of much larger size and more vigorous growth."

Shell-fish are here the chief support of the natives as well as of the wild animals. At Low's harbor a sea-otter was killed in the act of carrying to its hole a large Volute, and in Tierra del Fuego one was seen eating a cuttle-fish.—DARWIN.

A certain number of Arctic genera, which are not found in

warm seas, here reappear, such as *Trophon*, *Buccinum*, *Margarita*, *Puncturella*, *Buccinopsis*, *Admete*, *Astarte*, *Cyanium*, etc. Usually, however, these are representative rather than identical genera, the species of *Trophon*, for instance, constituting a peculiar group, with species extending to New Zealand and Cape of Good Hope, but differing from the typical *Trophon* of the Arctic mollusca.

Kerguelen's Islands have been recently visited by several scientific expeditions and 58 species of mollusks collected, 13 of which occur on the South American coast, 6 belong to the New Zealand fauna, 4 are found at the Cape of Good Hope. Among them is the genus *Struthiolaria* belonging to the Australo-Zealandic province: the other genera are South American. *Chiton Belknapii* of the Pacific, *Lasæa rubra* of European seas, and *Terebratulina septentrionalis* of Boreal America also reappear here.

Some peculiar species, together with several stragglers from other regions and faunas have been discovered at the islands of Marion, Crozet and Prince Edward.

Fischer surmises that there exists a circumpolar fauna in the Antarctic as well as in the Arctic regions, and thinks the occurrence of a number of mollusks of the Magellanic province in the south of the New Zealand Archipelago and at the Cape of Good Hope indicates that such is the fact.

XVI. Patagonian Province.

From S. Catharina, Brazil, south of the Tropic, to P. Melo, Patagonia. This coast-line has shifted considerably since the era of its present fauna. M. d'Orbigny and Mr. Darwin observed banks of recent shells, especially *Potamomya labiata*, in the valley of La Plata and the Pampas around Bahia Blanca. Mr. Cuming also met with *Voluta Brasiliana*, and other existing shells, in banks 50 miles inland. Of 79 shells obtained by M. d'Orbigny on the coast of N. Patagonia, 51 were peculiar, 1 common to the Falkland Islands, and 27 to Maldonado and Brazil. At Maldonado 37 species were found, 8 being special, 10 common to N. Patagonia, 2 to Rio, and 17 to Brazil. Of the latter 8 range as far as the Antilles; viz.:—

<i>Crepidula aculeata</i> .	<i>Macra fragilis</i> .	<i>Lucina semi-reticulata</i> .
“ <i>protea</i> .	<i>Venus flexuosa</i> .	<i>Plicatula Barbadosensis</i> .
<i>Pholas costata</i> .	<i>Modiola viator</i> .	

At Bahia Blanca, in lat. 39° S., the most abundant shells observed by Mr. Darwin (p. 243) were:—

<i>Oliva auricularia</i> .	<i>Oliva tehuelchana</i> .	<i>Voluta angulata</i> .
“ <i>puelchana</i> .	<i>Voluta Brasiliana</i> .	<i>Terebra Patagonica</i> .

M. d'Orbigny's list also includes the following genera:—

Octopus.	Lyonsia.	Solen.	Corbula.
Columbella.	Solecurtus.	Lutraria.	Pinna.
Bullia.	Æolis.	Donacilla.	Mytilus.
Pleurotoma.	Paludestrina.	Nucula.	Lithodomus.
Fissurellidæa.	Scalaria.	Leda.	Pecten.
Panopæa.	Natica.	Cytherea.	Ostrea.
Periploma.	Chiton.	Petricola.	

XVII. *Caribbean Province.*

The Gulf of Mexico, the West Indian Islands, and the eastern coast of South America, as far as Rio, form the fourth great tropical region of marine life. The number of shells is estimated by Prof. C. B. Adams at not less than 1500 species, which is certainly an under-estimate. Of these 500 are described by M. d'Orbigny in Ramon de la Sagra's History of Cuba, and a small number of the Brazilian species in the same author's Travels in South America.

The coasts of the Antilles, Bermuda, and Brazil, are fringed with coral reefs, which attain their greatest development around the Bahamas, South of Florida, north of Cuba and at the Bermudas; and there are considerable banks of gulf-weed at some distance from the coast of the Antilles. The peculiar fauna of the coral reefs is therefore represented in the West Indies, but without the richness of zoological forms which characterizes it in the Indo-Pacific province.

The discovery of representatives of ancient genera once supposed to be extinct gives a peculiar interest to this Province. Such are *Pholadomya*, *Pleurotomaria*, and *Murchisonia*. The group *Melongena* belongs to this fauna and the neighboring Panamic province exclusively, although anciently extending to Europe.

The Caribbæan fauna contains a large number of species common to the West coast of Africa and to Panama; *Dolium galea* of the Mediterranean Sea is also found here. But the most remarkable circumstance is the presence of a number of Indo-Pacific forms, including a dozen species of *Triton*.

XVIII. *Transatlantic Province.*

The Atlantic coast of the United States was supposed by Prof. E. Forbes to consist of two provinces: (1) The *Virginian*, from C. Cod to C. Hatteras and (2) the *Carolinian*, extending to Florida; but no data were supplied for such a division, and the distribution of the shells does not warrant it. The total number of mollusca is about 300, and 60 of these range farther

north, quite a number being moreover common to Europe. These two regions are sometimes treated of together as the Pennsylvanian province.

I have already stated in treating of the Boreal Province that the barrier of Cape Cod has not influenced the distribution of the mollusca nearly so much as was formerly supposed; that some southern forms surmount it, and that many northern forms extend further southwards. On the other hand, the Gulf Stream has exercised a wonderful influence upon the fauna of the Southern shores of the United States, as far northwards as Fort Macon, N. Carolina, adding many semitropical forms to our mollusca.

Crepidula, Fulgur, large species of Venus and of Mactra are among the characteristic shells of a region which possesses but little claim to the title of a distinct province. Lingula, one of the most ancient of genera, is now nearly confined to the Australian and Philippine seas; yet a peculiar species is found in the waters of North Carolina; and not only a Dolium, but a new Pholadomya, the second living species of that ancient group have been recently dredged by Verrill in New England waters. *Littorina litorea* is a comparatively recent importation from northern Europe. It was first detected, a few years since on the Nova Scotia coast, where it had probably arrived on ballast; we next hear of it as somewhat plentiful around Boston, and it has now spread southwestwards, as far as New Haven, Conn. The writer found it, in the summer of 1881, the most plentiful mollusk on the rocky coasts of Newport, R. I.

BATHYMETRICAL DISTRIBUTION OF MARINE MOLLUSKS.

The distribution of marine animals according to depth is subject to laws quite as evident as those which govern their geographical distribution. Messrs. Andouin and Milne-Edwards (1830), M. Sars (1835), Ørsted (1844), Forbes (1841-2), have studied this subject, and proposed schemes of bathymetrical classification, all founded upon the supposition that the existence of animal life at considerable depths was impossible. Of late years four zones or vertical regions have been recognized; and the deep-sea dredgings of the past fifteen years (having fully demonstrated the existence of life at vast depths, a fifth zone may now be added.

The dredging expeditions which have established the above highly interesting fact, and so largely increased our knowledge of the distribution of the Mollusca are: American, those of the *Corwin* (1867), *Bibb* (1868-1869), *Blake* (1877-1878), *Fish Hawk* (1880-1881); English, *Lightning* (1868), *Porcupine* (1869-1870), *Challenger* (1873-1876), *Valorous* (1875); Scandinavian,

Josephine (1869), *Voringen* (1876); French, *Travailleur* (1880). No greater depth than about 4000 fathoms has been obtained, and the average depth appears to be from 1500 to 1800 fathoms. At the great depth of 2300 fathoms, the naturalists of the *Porcupine* obtained the following mollusks, including their soft parts: *Syndosmya nitida*, *Dacrydium vitreum*, *Pecten fenestratus*, *Neæra obesa*, *Dentalium candidum*.

The water of the ocean gradually becomes cooler from the surface to the bottom. The cooling is rapid between the surface and 250 fathoms, slow but regular between 250 and 850 fathoms, and almost without variation between 850 and 2300 fathoms. The following temperatures were obtained by the *Porcupine* at the mouth of the Gulf of Gascony, July 22, 1869.

Surface, 17° Centigrade; 82 French mètres,* 12° Centigrade; 137 mètres, 11° C.; 402 mètres, 10° C.; 731 mètres, 9° C.; 1005 mètres, 8° C.; 1188 mètres, 7° C.; 1280 mètres, 6° C.; 1462 mètres, 5° C.; 1645 mètres, 4° C.; 2560 mètres, 3° C.; 4452 mètres, bottom, 2.5° C.

Three of the five vertical zones of marine life are contained within the depths of surface to 50 fathoms, where the temperature decreases rapidly, and this change of temperature has, of course, marked influence upon all animal life, both directly and by governing the distribution of the plants upon which animals largely feed. Whilst the surface temperature varies greatly in different portions of the globe, the greater the depth the more tendency is there to uniformity, until finally, there is a body of water having the vast thickness of 1000 to 1500 fathoms, at the depth of from 1000 to 2500 fathoms, with scarcely any variation in temperature. It is evident that those mollusks which are able to live in any portion of this belt, may be expected also at its greatest depth, and that in proportion to the depth at which they live, their geographical distribution may increase. Another element which deserves notice is that a shore species in a northern latitude, may spread southwards retaining the temperature suitable to its existence, by seeking greater depths. These general facts are modified in particular localities, and the distribution of the mollusca thereby influenced. Thus the Mediterranean Sea, from a depth of 182 mètres (100 fathoms) to its bottom, 2743 mètres, maintains almost constantly the temperature 55° F., or through a thickness of 2500 metres. There are known to be ocean currents of both warmer and colder water having definite direction and continuous flow, and by means of

* A French mètre = 39 + inches, therefore 2 mètres rather more than equal a fathom (6 feet). To reduce the Centigrade readings to those of Fahrenheit's thermometer, $C^{\circ} \times \frac{9}{5} + 32 = F^{\circ}$.

these currents mollusks may spread into localities distant from their specific metropolis.

The five bathymetrical zones are:

1. Littoral. Between tide-marks.
2. Laminarian. From low water to 15 fathoms.
3. Coralline. From 15 to 50 fathoms.
4. Deep-Sea. From 50 to about 300 fathoms.
5. Abyssal. From 300 to 3000 fathoms, or more.

1. *The Littoral Zone* depends for its depth on the rise and fall of the tide, and for its extent on the form of the shore. The shells of this zone are more limited in their range than those which are protected from the vicissitudes of climate by living at some depth in the sea. The characteristic genera of rocky shores are *Littorina*, *Patella*, and *Purpura*; of sandy beaches, *Cardium*, *Tellina*, *Solen*, *Mactra*, *Natica*, *Donax*, *Petricola*, etc.; gravelly shores, *Mytilus*; and on muddy shores, *Lutraria* and *Pullastra*. On rocky coasts are also found many species of *Haliotis*, *Siphonaria*, *Fissurella*, and *Trochus*; they occur at various levels, some only at the high-water line, others in a middle zone, or at the verge of low water. *Cypræa* and *Conus* shelter under coral-blocks, and *Cerithium*, *Terebra*, *Natica*, and *Pyramidella* bury in sand at low water, but may be found by tracing the marks of their long burrows. The sea-shore collector will obtain principally littoral shells; with occasionally others washed ashore from greater depths; usually dead and empty.

2. *Laminarian Zone*. In this region, when rocky, the tangle (*Laminaria*) and other sea-weeds form miniature forests, the resort of the vegetable-feeding mollusks — *Lacuna*, *Rissoa*, *Nacella*, *Trochus*, *Aplysia*, and various *Nudibranchiata*. On soft sea-beds bivalves abound and form the prey of *Buccinum*, *Nassa*, and *Natica*. From low-water to the depth of one or two fathoms on muddy and sandy shores, there are often great meadows of grass-wrack (*Zostera*) which afford shelter to numerous shell-fish, and are the haunt of the cuttle-fish and calamary. In tropical seas, the reef-building corals often take the place of sea-weeds, and extend their operations to a depth of about 25 fathoms. They cover the bottom with living verdure, on which many of the carnivorous mollusks feed, while some, like *Ovulum* and *Purpura*, browse on the flexible *Gorgoniæ*. To this zone belong the oyster-banks of our seas, and the pearl-fisheries of the south; it is richer than any other in animal life, and affords the most highly colored shells.

3. *Coralline Zone*. In northern seas the belt of sea-weed that fringes the coast is succeeded by a zone where horny zoophytes abound, and the chief vegetable growth consists of *Nullipore*, which covers rocks and shells with its stony-looking incrusta-

tions. This zone is inhabited by many of the predacious genera—*Buccinum*, *Fusus*, *Pleurotoma*, *Natica*, *Aporrhais*, *Philine*, *Velutina*; and by vegetable feeders, such as *Fissurella*, *Emarginula*, *Pileopsis*, *Eulima*, and *Chemnitzia*. The great banks of scallops belong to the shallower part of this region, and many bivalves of the genera *Lima*, *Arca*, *Nucula*, *Astarte*, *Venus*, *Artemis*, and *Corbula*.

4. *Deep-sea Zone*. From 50 to 100 fathoms the Nullipore still abounds, and small branching corals to which the *Terebratulæ* adhere. In northern seas the largest corals (*Oculina* and *Primnoa*) are found in this zone, and shells are relatively more abundant, owing to the uniformity of temperature at these depths. These deep-water shells are mostly small and destitute of bright colors; but interesting from the circumstances under which they are found, their wide range, and high antiquity. Amongst the characteristic genera are *Crania*, *Thetis*, *Næra*, *Cryptodon*, *Yoldia*, *Dentalium*, and *Scissurella*. In the mud brought up from deep water may be often found the shells of *Pteropoda*, and other mollusca which live at the surface of the sea.

5. *Abyssal Zone*. The fauna of this zone and its distribution are as yet hardly known. Mollusks continue abundant at from 300 to 1200 fathoms, but the number of species appears to be small. At the depth of 2435 fathoms, the Porcupine Expedition obtained five species, and at 2740 fathoms the Challenger Expedition dredged three pelecypods, *Arca*, *Limopsis*, and *Leda*.

Usually the mollusks of this zone are of small size, not highly colored, with a white, thin and translucent shell. The visual organs are rarely deprived of pigment; *Eulima stenostoma*, *Pleurotoma nivalis*, and *Pecten fragilis* are stated to be blind.

The dominant forms of great depths are the Scaphopoda (*Dentalium*, *Siphodentalium*, *Cadulus*), the tetrabranchiate Gastropoda (*Philine*, *Cylichna*, *Utriculus*, *Scaphander*, *Actæon*, some species of *Pleurotoma* and *Fusus*), a few of the rhipidoglossata (*Scissurella*, *Puncturella*, *Cyclostrema*, *Seguenzia*), and some lamellibranchs (*Arca*, *Limopsis*, *Nucula*, *Leda*, *Malletia*, *Lima*, *Pecten*, *Amussium*, *Dacrydium*, *Axinus*, *Pecchiolia*, *Syndosmya*). Brachiopods are also found; one species, *Terebratula Wyvillei*, at a depth of 3000 fathoms.

Wyville Thomson has compared these abyssal shells with the cretaceous fauna, but they are not at all related, resembling rather the pliocene fauna of Italy, and the recent fauna of less depth in the Arctic and Antarctic seas—where analogous temperature prevails, and whence the species may have immigrated.

In 1863, S. Lovén emitted the opinion that a fauna of identical character extends from pole to pole, traversing all the degrees

of latitude. Thomson has arrived at the same conclusion; which appears probable from the number of identical abyssal species already obtained from far distant localities.

That mollusks are able to subsist through a great range of depth may be shown by the five species obtained by the *Porcupine* at 4451 mètres:—

Dentalium candidum, 749–2010–3200 m.

Dacrydium vitreum, 54–5027 m.

Syndosmya nitida, 7–200 m.

Neæra obesa, 36–73 m.

Pecten fenestratus, 91–457 m.

Terebratula Wyvillei lives between 1891 and 5300 mètres.

Mr. W. H. Dall, from the study of the extensive dredgings made by the “Blake” in the Gulf of Mexico (Bull. Mus. Comp. Zool., vi, 1880), has been able to fully illustrate the range of bathymetrical distribution; the material studied embracing nearly 500 species belonging to not quite 100 genera, and obtained from depths varying from a few fathoms to 1920 fathoms. Many species range from 30 to over 800 fathoms; a fact of extensive distribution which had never been so clearly indicated before, as most of the deep-sea expeditions omitted carrying their investigations continuously from the abyssal into the littoral regions. Mr. Dall finds that, whilst many species have a limited vertical range, a fair proportion extend from littoral to abyssal; of these about ten per cent. (in the Gulf of Mexico) belong to boreal or cold-water forms.

LAND REGIONS.

Distribution of Land and Fresh-water Shells.

The boundaries of the Natural-History land-regions are more distinctly marked, and have been more fully investigated, than their counterparts in the sea. Almost every large island has its own fauna and flora; almost every river system its peculiar fresh-water fish and shells; and mountain-chains like the Andes appear to present impassable barriers to the “nations” of animals and plants of either side. Exceptions, however, occur which show that beyond this first generalization there exists a higher law. The British Channel is not a barrier between two provinces, nor is the Mediterranean; and the Desert of Sahara separates only two portions of the same zoological region. In these and other similar instances the “barrier” is of later date than the surrounding fauna and flora.

The specialization of island faunas is one of the most astonishing facts connected with this subject. Almost every large island, when surrounded by deep water, has its peculiar types of

genera of terrestrial mollusca; Cuba, Jamaica, Hayti, Madagascar, New Caledonia, Australia, the Philippines, etc., may be cited. Even small islands, such as Malta, Lampedusa, Cos, Naxos, Corfu, Zante, Lesbos, Eubæa, Rhodes, in the Mediterranean Sea, are characterized by the presence of species not found elsewhere. The exceptions are, as in the case of England, where the present species, identical with those of the adjacent continent, antedate the formation of the British Channel.

It has been often remarked that the northern part of the map of the world presents the appearance of vastly-extended, continental plains, much of which is, geologically speaking, new land. In the southern hemisphere the continents taper off into promontories and peninsulas, or have long since broken up into islands. Connected with this is the remarkable fact that only around the shores of the Arctic Sea are the same animals and plants found through every meridian; and that in passing southward, along the three principal lines of land, specific identities give way to mere identity of genera; these are replaced by family resemblances, and at last even the families of animals and plants become in great measure distinct, not only on the great continents, but on the islands, till every little rock in the ocean has its peculiar inhabitants—the survivors, seemingly, of tribes which the sea has swallowed up (Waterhouse).

The two largest genera, or principal types of the land and fresh-water shells, *Helix* and *Unio*, have an almost universal range, but admit of many geographical subdivisions. Amongst the land snails are several species to which a nearly world-wide range has been assigned, sometimes erroneously, and often correctly, but usually only because they have been carried to distant localities by human agency. Land snails are in favor with Portuguese sailors, as “live sea stock;” and they have naturalized the common garden-snail of Europe (*Helix aspersa*) in Algeria, the Azores, and Brazil;* and *Helix lactea* at Teneriffe and Montevideo. *Achatina fulica* has been taken from Africa to the Mauritius, and thence to Calcutta, where it has been established by a living naturalist; and *Helix hortensis* has been carried from the old country to America, and naturalized on the coast of New England and the banks of the St. Lawrence, and elsewhere. *Bulimus Goodalli*, indigenous to the West Indies and South America, has been introduced into English pineries and to Mauritius. *Helix pulchella*, one of the small species found in moss and decayed leaves, inhabits Europe, the Caucasus, Madeira,

* French emigrants introduced this species twenty-three years ago at San Jose, California, where it still exists, within a limited area, and is gathered for food.

the Cape (introduced), and nearly all the northern portion of North America. *Helix cellaria* inhabits Europe and the Northern United States, and has been carried abroad with the roots of plants, or attached to water-casks, and naturalized at the Cape and New Zealand. *Testacella maugei* has been transported from the Canary Islands to England. *Helix similis*, a native of Eastern Asia, lives in South Africa, Australia, Polynesia, Brazil, the West Indies, etc., wherever the coffee-tree is cultivated. *Ennea bicolor* has a very similar distribution, by human agency. The Canary Islands, Azores and Madeira support a considerable number of European Helices, introduced with cultivated plants: even St. Helena has a half-dozen acclimated European species.

Several species of fresh-water pulmonates, *Limnæa*, *Physa*, *Planorbis*, are common to both continents: some of them well distributed over either, others apparently originating in one and introduced into the other. American species thus occur in England in isolated localities, and others known to be of European origin have from time to time been made known as inhabiting the United States.

The best known and most instructive instance of the spread of a bivalve mollusk is that of *Dreissena polymorpha*. Pallas discovered it in 1769 at the mouth of the River Volga, which empties into the Caspian Sea. It was subsequently found in the rivers flowing into the Black Sea, the Dneiper, Danube, etc. From the latter it is supposed to have been carried into Germany by the pontoon trains during the wars of Napoleon, and became known as a German mollusk in 1814; as English, toward 1824. In London they have caused trouble by growing in the water-pipes, and in 1834 they appeared in Edinburgh. They were discovered in Belgium in 1833, and their march into various parts of France has been heralded by various local collectors at periods extending from 1838 to 1866: so that in twenty-five years this mollusk spread throughout all the great hydrographic basins of France. If, says Fischer, this extension had occurred several centuries ago, it would have been impossible to ascertain the original locality of the species, except by reference to its fossil remains: these show that it did not exist in the quarter-naries of Western Europe, but that it occurred in the chalk of the Steppes.

The Old World and America may be regarded as provinces of paramount importance, having no indigenous species in common (except a few in the extreme north), and each possessing many characteristic genera.

AMERICA.	OLD WORLD.	AMERICA.	OLD WORLD.
Strebelia.	Daudebardia.	Tomocyclus.	Leptopoma.
Streptostyla.	Testacella.	Choanopoma.	Pupina.
Selenites.	Ennea.	Cistula.	Callia.
Guestieria.	Gonospira.	Geomelania.	Alycæus.
Stenopus.	Gibbus.	Trochatella.	Acme.
Sagda.	Parmacella.	Alcadia.	Pirena.
Binneya.	Hyalimax.	Lucidella.	Vibex.
Pallifera.	Geomalacus.	Bourcieria.	Melanopsis.
Anostoma.	Nanina.	Stoastoma.	Canidia.
Bulimus.	Parmarion.	Proserpina.	Paludomus.
Odontostomus.	Helicarion.	Ceres.	Lithoglyphus.
Liguus.	Boysia.	Chilina.	Lacunopsis.
Orthalicus.	Hypselostoma.	Pompholyx.	Benedictia.
Cylindrella.	Achatina.	Pachychilus.	Baïkalia.
Macroceramus.	Pseudachatina.	Pleurocera.	Lanistes.
Megaspira.	Limicolaria.	Goniobasis.	Navicella.
Strophia.	Columna.	Anculotus.	Ætheria.
Berendtia.	Bulinus.	Io.	Iridina.
Eucalodium.	Cataulus.	Tulotoma.	Spatha.
Rhodea.	Pterocyclos.	Melantho.	Galathea.
Simpulopsis.	Pomatias.	Lioplax.	Velorita.
Gæotis.	Otopoma.	Mulleria.	Batissa.
Peltella.	Craspedopoma.	Castalia.	Fischeria.
Amphibulima.	Diplommatina.	Monocondylus.	Cyrenella.
Homalonyx.	Aulopoma.	Rangia.	Glaucomya.

Oceanica contains comparatively few peculiar generic types. The following may be cited :

Athoracophorus.	Carelia.	Paryphanta.
Rhytida.	Achatinella.	Ameria.
Diplomphalus.	Auriculella.	Latia.
Placostylus.	Endodonta.	Ampullacera.
Partula.		

The malacological fauna of Oceanica is not intermediate in character between those of the Old and New Worlds; it has a distinct series of forms, nearest allied, however, to those of Asia, to which it approaches through the Malaysian Islands.

Woodward has adopted for the land regions the principal Botanical Regions, 27 in number, of Prof. Schouw, as given in Berghaus' Physical Atlas: they are mostly natural regions for the terrestrial mollusks, but several of them are not in accordance with the actual grouping of the species. Fischer has attempted in several instances to improve upon Woodward's divisions; successfully on the whole, although some of his regions, do not, we think, possess distinctive characters.

The regions of Fischer will be herein shortly described, and their correlation with those of Woodward is exhibited in the annexed table.

Zone.	FISCHER.		WOODWARD.	
	Regions.			
PALÆARCTIC.	{	1. Septentrional.	Germanic.	
		2. Mediterranean.	Lusitanian (part).	
		3. Central Asiatic.	(Wanting.)	
		4. Chinese.	China and Japan.	
		5. Japanese.	China and Japan.	
		6. Atlantic.	Lusitanian (part).	
PALÆOTROPICAL AFRICAN.	{	7. Central African.	African.	
		8. Western African.	African.	
		9. Southern African.	Cape.	
		10. Malgachian.	Yemen, Madagascar.	
		11. Afro-Arabic.	Yemen, Madagascar.	
PALÆOTROPICAL ORIENTAL.	{	12. Indian.	Indian.	
		13. Indo-Chinese.	Indian.	
		14. Indo-Malaysian.	Java, Borneo.	
		15. Philippine.	Philippines.	
AUSTRALIAN.	{	16. Austro-Malaysian.	New Guinea (part).	
		17. Australian.	{ Australian, North Austral. & Tasmanian.	
		18. Austro-Polynesian.	Polynesian.	
		19. Polynesian.	Polynesian.	
		20. Neozelandic.	N. Guinea (pt.) N. Zeal.	
NEANTARCTIC.	{	21. Patagonian.	Argentine, Patagonian	
		22. Chilian.	Chilian.	
NEOTROPICAL.	{	23. Peruvian.	Peruvian.	
		24. Columbian.	Columbian.	
		25. Brazilian.	Brazilian.	
		26. Mexican.	Mexican.	
		27. Caribbæan.	Antilles.	
NEARCTIC.	{	28. American.	American.	
		29. Californian.	Oregon & California.	
		30. Canadian.	Canadian.	

1. SEPTENTRIONAL REGION.

This includes the whole of the northern portion of the old world; it may be divided into two subregions:—

1. *European Subregion.* Its southern limits are the Pyrenees, the Alps, the Carpathians, the Caucasus. The forms are not numerous; something over 200 species of land shells, the greater part of which are found likewise inhabiting the Mediterranean region. They are usually small, and not conspicuous in coloring.

They are very numerous in individuals, and unlike the species of the United States, which occur mostly in moist, shaded woodlands, they are frequently found in exposed, sunny situations. The species are most numerous towards the southern boundary of the region, and in cold countries are few.

About twenty species of land and fresh-water mollusca are found in Iceland and the Faroë Islands. 127 species occur in Great Britain; two only of which *Limnæa involuta* and *Assiminea Grayana*, are peculiar to it. On the other hand several species are introduced (not indigenous). A few European species not now living in Great Britain, are found there as quaternary fossils; whilst some of the commonest living species are not found in the quaternary, hence must have become British within comparatively recent times.

The malacology of the northern, central and eastern portions of France presents no particular features; but in the neighborhood of the Vosges, Jura and Alpine ranges occur a few *Helices*, etc., belonging to mountainous regions. The southern and western parts of France include a large infusion of the species proper to the Mediterranean Province. The French quaternaries tell the same tale of the extinction of some species and subsequent introduction of others, as do those of Great Britain; among the former is a special group of small *Hydrobias*, called *Lartetia*.

The countries of the north of Europe contain approximately: Sweden, 136 species; Norway, 80; Lapland, 16; Finland, 75; Denmark, 133.

Helix harpa, Say, a minute American shell, is probably circumpolar in distribution as it has been found in Labrador, British America, Norway, Sweden and Lapland.

Germany possesses 248 species, of which 125 occur throughout Europe. The vast plains of Northern Russia have a fauna resembling that of Germany.

Siberian Subregion. In 1877, Westerlund enumerated 137 species, of which 48 are terrestrial and 89 fluviatile. A number of these are European species, several of them circumboreal; such as *Vitrina pellucida*, *Helix pulchella*, *Cionella lubrica*, *Pupa muscorum*, *Physa hypnorum*, *Limnæa auricularia*, *L. palustris*, *L. stagnalis*, *Planorbis albus*, *Margaritana margaritifera*, all of which recur in British North America and the northern parts of the United States.

There are a dozen or twenty special forms in Siberia, but they are mostly of European aspect, and in some cases are not really distinct from European species. In Lake Baikal, however, is a special fauna, one of the most distinctive in existence; it is characterized by a number of genera related to *Hydrobia* (represented in the Colorado Desert of N. America by the peculiar genus *Tryonia*), *Choanomphalus* (related to the Californian

genus *Carinifex*), *Valvata*, *Ancylus*, etc. Kamtschatka has six terrestrial and seven fluviatile species, three of the former, so far, peculiar.

The Amour territory, the North of China, Thibet and Turkestan, although excluded from this region, contain a large percentage of European forms.

2. MEDITERRANEAN REGION.

All the countries bordering on the Mediterranean, the Black and the Caspian Seas form a vast terrestrial region inhabited by a very varied fauna. This region is limited by the African desert, the Atlantic, the Alps, and to the east, by the Central Asiatic region—with the species of which it intermingles in such manner that certain authors consider the latter as a mere subdivision. The immense development of the genus *Clausilia* is characteristic of this region; and in a less marked degree, the number of species of *Buliminus*, *Testacella*, *Daudebardia*, *Calcarina*, *Pomatias*. Certain sections of the *Helices* also are hereunto restricted. Among the species distributed throughout the entire province may be cited *Bul. (Rumina) decollata*, *Helix (Calcarina) candidissima*, *aperta*, *vermiculata*, *Pisana*, *variabilis*, *pyramidata*, *acuta*, *Buliminus pupa*, *Ferussacia folliculus*, *Physa (Isidora) contorta*, *Melanopsis prærosa*, *Unio littoralis*, etc.

Fischer thus subdivides the region:

- a. Occidental or Atlantic Subregion.
- b. Meridional or Mediterranean Subregion: including the

{	Hispano-Barbaric Fauna.
{	Egypto-Syrian Fauna.
{	Hellado-Anatolic Fauna.
{	Italo-Dalmatian Fauna.
- c. Central or Pontic Subregion.
- d. Oriental or Caspian Subregion.

The first of these includes Portugal, North Spain and the West of France; it contains a number of characteristic forms, a few of which extend beyond its boundaries. Some of these species, however, are scarcely entitled to be considered more than varieties of mollusks having a more general distribution.

In the Mediterranean subregion there are, as Fischer has pointed out, several faunal provinces distinguished by characteristic groups of related forms, evidently derived from a common ancestry: such are the species of *Helix* belonging to the sections *Macularia* and *Calcarina*, those of *Melanopsis*, etc. The genus *Clausilia* is very rare in Spain, and wanting in its southern portion. In the Balearic Islands three-fourths of the species are Spanish, the rest mostly peculiar—including several *Helices* of the section *Jacosta*, only found there.

The shells of Northern Africa are more closely related to those of Spain than to those of Sicily, yet the ancient connection

of that island with the African continent is manifested by some species common to both countries, but wanting in Spain. In Algiers considerably over 300 species have been enumerated, including a number of *Helices* of the sections *Macularia* and *Helicella*, numerous species of *Ferussacia*, etc. A considerable number of species are peculiar. The Desert of Sahara contains very few forms.

Egypto-Syrian Fauna. The fresh-water shells of the Nile have a decidedly African character, *Ampullaria* and *Lanistes* being found in Lower Egypt, *Limicolaria*, *Physopsis*, *Ætheria* and *Spatha* in Upper Egypt. The terrestrial shells of Egypt, on the contrary, are evidently of Syrian type and derivation: the group *Macularia*, for instance, so characteristic of the Barbary States, being reduced to a single species, whilst Syrian groups include most of the *Helices*. Besides these, Syria itself contains a number of species of *Buliminus*, of *Clausilia*, section *Cristataria*, *Ferussacia*, *Melanopsis*, *Unio*, etc., which are peculiar to this country. No shells live in the Dead Sea.

Hellado-Anatolian Fauna. The shells of Asia Minor include many of those of Syria, with Northern colonies from the Pontic region and western ones from the Archipelago and Greece. The Asiatic coast of the Black Sea properly belongs to the Pontic fauna. The most interesting facts in connection with the distribution of mollusks in this region are the presence of the large typical *Zonites*, represented by four species, of numerous species of *Buliminus*, and of *Clausiliæ* belonging to the sections *Medora* and *Melinda*.

In Greece and its islands, the fauna has relationships with that of Dalmatia, Asia Minor and the Pontic region. The *Anchistoma* and *Campylæa* sections of *Helix*, *Buliminus* and *Clausilia* are well represented. The latter genus is enormously developed, including 25 out of the 75 species of land mollusks known to inhabit the island of Crete; with peculiar forms in many of the islands.

Dalmatia, Carniola, Carinthia and Croatia have a molluscan fauna related on the whole most nearly to that of Italy, although the three latter belong geographically to the Black Sea basin. Here again the development of *Clausilia* is remarkable, numbering 80 out of 254 Dalmatian terrestrial species, and including some of the largest forms of that genus in Europe. The *Helices* are represented especially by several large species of *Campylæa* and four species of *Zonites*. There are also several *Pomatias*. A special fauna of blind mollusks inhabits the caverns of Carniola, most of them being very much restricted in their distribution: they are very small species, and include a *Helix*, no less than nine species of *Zospeum* (*Pupa*), a *Bythinella* and two *Valvatæ*.

Italy and its islands contained in 1878, according to M. Pautucci, 534 species of land and fresh-water shells, a remarkable development of molluscan life. Of these, 230 species are inhabitants of Sicily, including a number of forms special to that island. The Helices are rich in the section Campylæa, 16 species, in Iberus, etc.; there are 80 species of Clausilia, and 22 of Pomatias.

The Pontic and Caspian subregions partake in general character with the Italo-Dalmatian fauna, with, nevertheless, a number of special forms in each. The basin of the Danube is characterized by the development of certain types of fresh-water univalve mollusks, Lithoglyphus, *Melania Hollandri* and *parvula*, Melanopsis. Transylvania possesses a particular form of Clausilia (Baleoclausilia), of which 5 species are known. In the Crimea are found 9 species of Buliminus, certain localized Clausiliæ, etc. The Turkish territory bordering on the Black Sea has 7 species of the group Pomatia (Helix). Transcaucasia has 160 species of land and fluviatile shells, 67 of which are supposed to be peculiar to the region.

The great richness of molluscan life in the Mediterranean Region, the abundance of individuals, and the thoroughness with which its localities have been explored, have combined to give it an importance beyond that of any other land region, both in conchological literature, and usually also in the cabinets of collectors. The Helicidæ alone will number considerably over a thousand nominal species—some of which, however, are merely races or geographical varieties. Clausilia, with its three hundred species, only finds a parallel in importance among cylindrical, many-whorled forms in the West Indian genus Cylindrella.

3. CENTRAL ASIATIC REGION.

The shells of Turkestan, Afghanistan and Thibet, are not well known. These countries have only been partially explored, and the hundred species which have been collected in their extensive territories, scarcely form a sufficient basis for a scientific estimate of the character of the fauna. Many of the species, of fresh-water univalves especially, are those common to Europe (and in some instances to North America); although there are some peculiar forms reported from each of the countries comprising the region. There are no species of Pomatias and but two or three of Clausilia, only one Unio; but Helices are numerous, belonging mostly to North European groups. It may well be doubted whether this should rank as a distinct region, for it partakes, as far as known, too largely of the characteristics of the Septentrional and Mediterranean Regions.

4. CHINESE REGION.

The conchological fauna of the North of China is palæarctic in character, whilst that of the central and southern provinces and of the islands is palæotropical. There are a number of special groups of Helices, such as Plectotropis, Acusta, Camena, Ægista, Corilla, etc.; as well as a few Clausilia, Stenogyra and Buliminus. The more southern regions include some tropical forms (of which a large proportion, as in tropical America, are operculated). Among these may be named Streptaxis, Pupina, Cyclotus, Diplommata, Cyclophorus, Alycæus, Realia, Paxillus, Helicina. The rivers are filled with magnificent species of Paludina and Melania, but fresh-water pulmonates are very few. Bivalve mollusks of the Corbiculadæ and Unionidæ are very numerous; the species of the former numbering over 50, exceeding in variety any other region; whilst the Unionidæ (including the special group Dipsas), are developed beyond any region except that of North America—more than 100 species being already known, although most of the streams have not been thoroughly explored.

5. JAPANESE REGION.

Nearly 200 species of land and fluviatile mollusks are known; of which 73 belong to Helix and Hyalinia, 36 to Clausilia (several gigantic forms—for the genus), 23 are operculated, etc. The Helicidæ and operculates are of Chinese groups mostly; there are 8 species of Paludina, and 5 of Melania; but the Unionidæ, so plentiful in China, are here scarce, numbering but a dozen species; there are 9 species of Corbiculadæ.

Several of the species of North Japan are of extensive distribution:

Helix (Hyalinia) nitida—Europe. *H. (Hyalinia) minuscula*, N. Am.

Limnæa auricularia and *ovata*, and *Planorbis albus*, Europe; *Bythinea striatula*, Amour; *Anodonta herculea* and *Margaritana Dahurica*, Siberia.

6. ATLANTIC REGION.

The Azores, Canaries, Madeira and Cape Verd Islands contain conchological faunas astonishing in their individuality. The theory that these islands are the last vestiges of a vast Atlantic continent is scarcely in accord with the distribution of their shells, for not only are the species usually restricted to each group, but even some of the generic groups are similarly localized; nor have these any relationship to the forms of the African, European or American faunas. European species are numerous, it is true, but they appear to have been accidentally

introduced and acclimated since the occupation of these islands by the Spaniards and Portuguese, as they are confined to the cultivated portions of the islands and do not occur in the latest fossil deposits. The genus *Craspedopoma* is characteristic of this fauna. No species of *Unio* occur, and in the Azores, not a single species of fluviatile mollusca. In Madeira the characteristic groups of *Helices* are *Leptaxis*, *Janulus*, *Actinella*, *Ochtephila*, *Phlebecula*, *Tectula*; in the Canaries, *Hemicyclus*, *Moniliaria*, etc. The ancient sandy dunes of Caniçal, at the eastern extremity of Madeira and in Porto Santo, contain numerous terrestrial mollusks, some of which have not been found in a living state. As the fossil examples of several species are larger than their living descendants, it is possible that some of these species reputed to be extinct have only degenerated. It is a remarkable fact that some of the commonest living species are not found fossil, whilst others, now extremely scarce, occur abundantly as fossils. *Helix tiarella* was supposed to be extinct until 1855, when Mr. Wollaston detected it alive in two almost inaccessible spots on the north coast of Madeira. The degeneration of the land shells in variety and size may be the result of a modern change of physical conditions brought about by human agency. The annual fall of rain is now 29.82 inches, whereas it was remarked by Columbus, nearly 400 years ago, "that, formerly, the quantity of rain was as great in Madeira, the Canaries, and the Azores, as in Jamaica, but since the trees which shaded the ground had been cut down, rain had become much more rare."

In the Azores there are 71 species, in Madeira 164, in the Canaries 189, Cape Verd 40; some of these are common to two or more groups, and some of the 50 introduced species in each case form part of the enumeration.

7. CENTRAL AFRICAN REGION.

This region, limited to the North, by the Desert of Sahara, includes the whole of intertropical Africa, with the exception of the basin of the Gulf of Guinea. Some of its species are distributed northward, following the course of the Nile, as far as Lower Egypt. The characteristic genera are *Limicolaria*, *Achatina*, *Ennea*, *Lanistes*, *Ætheria*, *Iridina* and *Spatha*. There are scarcely any *Helices* and the operculated land shells are very few. The three first genera enumerated are bulimoid land shells, *Achatina* including a number of very large species, only comparable in size with the *Bulimi* of the *Borus* group inhabiting Brazil, etc. There are a few fresh-water pulmonates, the *Physæ* being represented by the groups *Physopsis* and *Isidora*; but most of the fluviatile univalves are gill-breathers, including *Melania*, *Paludina*, *Ampullaria*, and the peculiarly African group *Lanistes* (reversed *Ampullariæ*). There are some *Unios*,

but the bivalves are principally Spatha, Iridina, and the fresh-water oyster, *Ætheria*. The Corbiculadæ are represented by the genus *Cyrenella* and two species of *Corbicula*. There are two African species of *Dreissensia*; both smaller than the *D. polymorpha*, which has spread with such amazing rapidity throughout Europe.

In Lake Tanganyika occur two special genera, viz.: *Tiphobia*, somewhat resembling the American genus *Io*, and perhaps a Melanian, and *Neothauma*, a group of the Paludinidæ; besides some mollusks simulating marine genera, such as *Trochus*, *Littorina*, etc. A number of species of *Melania* have been described from Lake Nyassa, but I think that they are mostly extreme forms of *M. tuberculata*, Müller. This lake contains several *Lanistes*, *Paludina*, *Physa*, etc., with a *Unio* and two *Spathas*.

The few African Cyclostomæ mostly occur upon the East Coast, Mozambique, Zanzibar, etc.

8. WEST AFRICAN REGION.

The malacological fauna of intertropical West Africa appears to be very rich, although the country is far from being thoroughly explored. With such characteristic genera as *Columna*, *Perideris*, *Pseudachatina*, *Streptostele*, *Galatea*, *Fischeria*, there are associated others which indicate relationship with Central Africa; these are *Achatina*, with equally large species, *Ennea*, and particularly the fluviatile genera *Ampullaria*, *Lanistes*, *Isidora*, *Physopsis*, *Iridina*, *Spatha*. Only two operculated land snails are known. The river mouths abound with brackish-water shells *Tympanotomus*, *Capsella*.

In Guinea, Morelet enumerated in 1868, 141 species, of which were *Helix* 6 (mostly of the group *Nanina*), *Streptaxis* 5, *Limicolaria* 7, *Achatina* 7, *Perideris* 10, *Stenogyra* 3, *Ennea* 5, *Melania* 5, *Pirena* 3, *Neritina* 4, *Unionidæ* 5, etc.

In the Gabon region about 50 species are catalogued also by Morelet. The characteristic genus is *Pseudachatina*, including 5 species. Some of the largest *Achatinæ* are found in this district, but the metropolis of this genus is in Angola and Benguela, from which 16 species have been sent. Here the fresh-water pulmonates are unexpectedly largely developed; there are 3 *Planorbis*, 4 *Limnæa*, 10 *Physa*.

The little, mountainous Prince's Island affords 25 species; its specialties being the genera *Columna*, 3 species, and *Streptostele*, 4 species.

The Island of St. Helena is 1200 miles from the nearest African coast of Benguela. It is entirely volcanic. The indigenous plants are all peculiar, and not more related to those of Western Africa than to Brazil. The land shells are all peculiar, except a

few acclimated European species, and are of 10 species only; but as many additional species are found as dead shells only, rarely retaining their color and translucency. They are found beneath the surface soil in the sides of ravines worn by the heavy rains, at a height of 1200 to 1700 feet. "Their extinction has probably been caused by the entire destruction of the woods, and the consequent loss of food and shelter, which occurred during the early part of the last century" (Darwin's Journal, 488). Of the dead shells thus found, the only species which still survives is *Succinea Bensoniana*. Among the extinct species are 7 *Bulimus*, including the curious *B. aurisvulpina*, and belonging to two groups, both special to the island. The *Helices* appertain to *Endodonta*, a Polynesian group. Three species of *Succinea* form the special group *Helisiga*, and live in high parts, on the leaves of arborescent compositæ. Thus the ensemble of characters of the molluscos fauna is original, and shows that St. Helena has been insulated since a very early period.

Ascension Island, 800 miles N. W. of St. Helena, is not known to possess any molluscos inhabitants, except a slug, *Limax Ascensionis*.

9. SOUTH AFRICAN OR CAPE REGION.

About 100 species have been collected in this region. The genus *Helix* is very abundant, contrasting with the scarcity of heliciform shells in intertropical Africa. The *Helices* belong to two types, *Dorcasia* 5 sp.; *Pella* 10 sp.; and there is also the large diaphanous *Helix Caffra*, the mollusk of which is carnivorous, and is made the type of the genus *Ærope*. There are 11 sp. of *Achatina* and 12 of *Ennea*, and a few *Cyclostomidæ*, 4 *Unionidæ*. The genera *Physopsis*, *Isidora* and *Spatha* are also represented, as throughout Africa.

10. MALGACHIAN REGION.

This includes, besides Madagascar, the islands of Bourbon, Mauritius, Rodriguez, the Comoros and Seychelles. Whilst the specific forms are peculiar to each island, the genera are common to all and thus unite them into a single malacological province. We find here a large development of carnivorous species having pupiform shells, *Ennea*, *Gibbus*; and the *Cyclostomidæ* are predominant, attaining their greatest representation in Madagascar, where many of them are spirally ridged (*Tropidophora*). There is only one *Helicina*, at the Seychelles.

In Madagascar there are more than 150 species of terrestrial and fluviatile mollusks. The *Helices*, 15 in number, are beautiful, and mostly belong to the genera *Helicophanta* and *Ampellita*: one of them *H. viridis* is a *Cochlostyla*—a Philippine Island group. There are 47 species of *Cyclostoma*, 13 *Neritina*,

7 *Melania*, 4 *Pirena*, a few *Limnæa*, *Physa*, *Planorbis*, *Ampullaria*, *Paludomus*, *Paludina*, *Lanistes*, etc. A very doubtful *Unio* and a *Cyclas* are the only bivalves found in this region. As might be expected, Madagascar, besides the special forms of the region, possesses some purely African genera; but these may have been introduced. The dunes of Cape St. Marie, where occur the bones of the gigantic extinct bird, *Æpyornis*, contain a few equally extinct shells, mixed with those of species still living.

About fifty species are known from the Comoro Islands, 11 of which are *Ennea*.

The island of Bourbon contains 69 species, 9 of which are operculated; and that of Mauritius a richer fauna, including 28 species of *Gibbus*—of which form it may be considered the metropolis—8 of *Omphalotropis*, etc. *Gibbus Lyonetianus*, one of the most bizarre-looking of land shells, appears to be rapidly becoming extinct. The island of Rodriguez possesses a fauna resembling that of Mauritius. The Seychelles contain two large *Helices* (*Stylodonta*) and the singular slug *Mariella Dussumieri*. The genera *Cyathopoma*, *Leptopoma* and *Helicina* are representatives of Asiatic forms, as well as the species *Ennea bicolor* and *Helix similaris*—the two latter acclimated throughout this region.

11. AFRO-ARABIC REGION.

The S. W. Highlands of Arabia (Yemen), which form a botanical province isolated by rainless deserts to the north, Abyssinia, the island of Socotra, and the African shore of the Gulf of Aden form a region but little known, but which differs sensibly from the African and Indian faunas. In Arabia and Socotra, *Ennea*, *Vitrina*, *Buliminus*, *Opeas*, *Cæcilianella*, *Pupa*, *Cœlostele*, *Isidora*, *Clyclostoma*, *Otopoma*, *Lithidion* and *Melania* are found. There are no *Helices*; *Buliminus* 14 sp.

The fauna of Abyssinia is curious alike for the absence of African genera, such as *Ætheria*, *Iridina*, *Galatea*, *Achatina*, *Lanistes*, and for the intrusion of forms from other regions. The latter include 2 species of *Limicolaria*, several European species (*Succinea*, *Limnæa*, *Helix*), some *Buliminus*, etc. There is not a single species of operculated land shells, but there are 2 *Clausilia*, 12 *Pupa*, 8 *Vitrina*, 9 *Subulina*; *Paludina* occurs, but no *Ampullaria*. There are 3 *Uniones*, a *Corbicula* and a *Cyclas*.

12. INDIAN REGION.

This province has been very well studied, and the rich results are included in the magnificent "Conchologia Indica," by Hanley and Theobald, published in 1876. Among the most remarkable terrestrial genera may be cited: *Anadenus* 2 sp., *Vitrina* 12, *Succinea* 10, *Lithotis* 2, *Nanina* (sections *Macrochlamys*, *Xesta*,

Ariophanta) 50, Helix (sections Plectopylis, Plectotropis. Eurystoma, Trachia, Planispira, Corella, Oxytes) 21, Boysia 1, Streptaxis 4, Ennea 6, Buliminus 46, Cyllindrus 5, Electra 53, Clausilia 3; and the following operculated forms: Cyclotus 2, Mychopoma 2, Cyathopoma 21, Spiraculum 3, Pterocyclos 6, Alycæus 53, Opisthopoma 5, Diplommatina 2, Nicida 6, Scabrina 1, Cyclophorus 29, Lagocheilus 1, Ditropis 3, Tropidophora 1, etc.; in all nearly 400 species. The fluviatile shells belong to the genera Limnæa, Planorbis, Ancyclus, Camptoceras (special), Camptonyx (special), Valvata, Bythinia, Paludina, Amnicola, Stomatodon (special), Tricula (special), Melania, Canidea and Clea (fresh-water Buccinidæ), Paludomus, Ampullaria, Neritina, Navicella, Unio, Corbicula, Velorita (special), Cyclas, Pisidium.

The genera Tanysiphon, Scaphula (Arcidæ), Novaculina (Solenidæ), Stenothyra and Oncidium live in the estuaries. Finally Cremnoconchus appears to be a terrestrial Littorina.

The various provinces of the vast Indian peninsula show remarkable diversity in altitude, climate and vegetation, and the region might be subdivided, although it is throughout characterized by the presence of certain peculiar forms which rather trenchantly separate it from other provinces. That portion which undoubtedly presents the most distinctive features is the island of Ceylon, which, like most insular faunas, is particularly rich in species. 250 forms are recognized from this island, including 49 Nanina, 23 Cyclophorus, 16 Cataulus, and 38 Paludomus (in Paludomus mostly varieties only). Two of the groups of Helices, Acavus and Corilla, are peculiar to the island, Acavus including some of the most beautiful of the Helicidæ. Ceylon has, perhaps, quite as much claim to be treated as a distinct fauna, as several of the other regions of Woodward and Fischer.

13. INDO-CHINESE REGION.

This region includes Assam, Burmah, Aracan, Pegu, Cambodia, Siam, Malacca, Singapore, Pulo Penang, Annam, Laos, the islands of the Nicobar and Andaman groups in the Gulf of Bengal, etc. It is much richer in mollusks than even the Indian peninsula, the operculated pulmonates especially being astonishingly developed; such as Cyclophorus, Lagocheilus, Pterocyclos, Rhlostoma, Alycæus, Diplommatina, Pupina, Rhaphaulus, etc. The most abundant non-operculated pulmonates belong to the genera Nanina, Helix, Amphidromus, Hypselostoma, Electra, Clausilia, Vitrina, Streptaxis. The fresh-water gastropods are Paludina, Ampullaria, Melania, Pachydrobia, Lacunopsis, Julienia, Canidea. The acephala are Unio, Pseudodon, Anodonta, Arconaia, Solenaia, Dipsas, Cyrena, Corbicula, Scaphula (fresh-water Arca) and Modiola, of which a species lives in Lake Tonli-

Sap. In the Unionidæ, some of the generic forms are closely allied to So. American genera, as *Pseudodon* to *Monocondylæa*, *Solenaia* to *Mycetopus*, *Arconaia* to *Hyria*. The Andaman and Nicobar Islands each possess many peculiar species.

14. INDO-MALAYSIAN REGION.

The islands of Sumatra, Java, Borneo, the Celebes, etc., form a natural insular region; to which the fauna of the peninsula of Malacca is quite as closely related as it is to that of the Indo-Chinese region to which it is attached. The section *Amphidromus*, of *Bulimus*, is the most characteristic form; but *Nanina* is largely distributed, and represented by its most beautiful species; *Clausilia* is found in Sumatra, Java and Borneo; the genera of operculated land shells are numerous; *Melania* predominates among the fluviatile mollusks.

The mollusks of this region are most nearly related to those of Indo-China.

But little is known of the mollusks of Sumatra; most of the described species being common to Borneo and Java. In Java 191 species have been collected, 14 of which are operculated, 82 fresh-water, 17 common to Sumatra.

Borneo, which is far from being completely explored, yields 167 species, of which 45 are operculated, 45 fresh-water. Of these 167 species, 19 live also in Java, 13 in Sumatra, 16 in the Indo-Chinese province, 18 in the Philippines; 100 species are peculiar to the island. The brackish-water mollusks are remarkable: *Pholas rivicola* burrows in floating logs used as landing places, twelve miles from the sea, up the Pantai River. The mangrove swamps abound with *Cerithidea*, *Terebralia*, *Potamides* and *Quoyia*; *Auricula* and *Scarabus* inhabit damp woods.

15. PHILIPPINE REGION.

The extraordinary richness of these islands has been developed mainly by the researches of Cuming and Semper. The climate is equable, with a temperature like that of South China (66° – 84°), woods are prevalent and the rains heavy—all circumstances favorable to the abundance of land shells. This region has been called the paradise of mollusks, and in fact, nowhere else upon the surface of the globe is there such a rich collection of gorgeously colored shells—classed as *Helix* or *Bulimus* according to the degree of elongation of the spire. It is supposed that, as in the West Indian Islands, the fauna of each island is largely peculiar to itself, but we do not possess the means of verifying this supposition. The list prepared by Kobelt comprises 586 species, 65 of which are operculate. There are 108 fluviatile gastropod mollusks. The *Helices* alone include about half the total number of species, and of these the characteristic

genus *Cochlostyla* has no less than 211 species. The bulimoid forms of *Cochlostyla* are many of them large and highly colored, under a thin, hydrophanous epidermis, almost like the bloom on a plum, and the bands become translucent when wetted. There are 50 species (or varieties) of *Melania*, 38 of *Neritina*; the bivalves consist of *Batissa*, 3; *Corbicula*, 7; *Cyrena*, 3; *Anodonta*, 1.

16. AUSTRO-MALAYSIAN REGION.

This division includes the islands lying between Australia and the Philippines, that is to say: the Celebes, Moluccas, New Ireland, New Britain, New Guinea, and the Admiralty, Louisiade and Solomon Islands.

In these islands *Helix* is largely developed; the group *Geotrochus* being characteristic, although wanting in the Celebes; but these islands, situated at the eastern extremity of the region, have a fauna of ambiguous character, including with a number of special species, many which approach those of the Philippines and Malaysia.

In the Moluccas more than 100 species are known, 28 of which are operculated. In New Guinea there are 90 species, 35 of which are *Helices* of the sections *Chloritis*, *Planispira*, *Papuina*, and principally, *Geotrochus*. *Leucoptychia* and *Perrieria* are peculiar genera. The Louisiade Archipelago has yielded as yet but few shells; including 4 handsome species of *Geotrochus*, and a large *Pupina*. In the Admiralty Islands there are 44 species, according to Kobelt, including 25 *Helices*, of which 14 are *Geotrochus*. The Central Polynesian genus *Partula* is here represented by 4 species. The 64 species of New Ireland and New Britain include *Geotrochus* 4, *Partula* 2, *Melania* 13, *Neritina* 16. The fauna of the Solomon Islands and New Georgia is exceedingly rich: more than 160 species, have been described, and the number is constantly augmenting notwithstanding the difficulty of exploring countries peopled by anthropophagous tribes. Heliciform shells predominate; principally *Geotrochus*, 60 sp.; *Trochomorpha*, 21 sp., and *Nanina*. There are a dozen species of the group *Placostylus* (*Bulimus*) of which *B. Cleryi* is the most remarkable. Relationship with the Polynesian fauna is shown by the occurrence of species of *Partula*, *Diplommatina*, *Pupina*, *Realia*, *Helicina*; with the Austro-Polynesian fauna, by that of *Placostylus*.

17. AUSTRALIAN REGION.

The Australian continent has only been partially explored for shells, those of the eastern coast being best known, whilst the west has so far yielded but few species—including many *Bulimi*. In North Australia are found *Helices* of the group *Xanthomelon*,

and a *Geotrochus*. *Physa*, *Amphipeplea*, *Paludina*, *Melania*, *Cyrena* and a *Solenaia* live in its waters: *Amphipeplea* being a characteristic genus. In Queensland, the *Helices* belong to the sections *Panda*, *Trochomorpha*, *Pedinogyra*, *Hadra*, *Galaxias*, *Geotrochus*, etc. New South Wales has a fauna less tropical than that of Queensland; *Pupina* diminishes in importance, and *Helicina* disappears. Three species of *Athoracophorus* occur, a slug essentially Australian; also several *Unios*. The *Helices* are largely represented and mostly of the same sections occurring in the other provinces. In Victoria and South Australia the *Helices* are mostly of the section *Hadra*. *Paryphanta*, a New Zealand genus, is represented by *P. atramentaria*. Tasmania has 115 species, 79 terrestrial and 36 fluviatile. Only ten of the terrestrial species are common to the Australian continent, and *Pupa*, *Pupina*, *Helicina* and *Tornatellina*, genera found in the south of Australia, are here absent. As in Australia, the fresh-water gastropods are numerous; among them is a species of the American genus *Gundlachia*.

18. AUSTRO-POLYNESIAN REGION.

Includes the New Hebrides, New Caledonian and Viti Archipelagos, with a very remarkable fauna. *Geotrochus* disappears and *Bulimi* of the group *Placostylus* become predominant. The slug *Athoracophorus*, the heliciform carnivores *Rhytida* and *Diplomphalus*, a few species of *Partula*, etc., occur.

About 60 species are credited to the New Hebrides, and nearly 400 to New Caledonia and the Loyalty Isles, including 46 *Placostylus*, 27 *Melampus*, (an extraordinary development of *Auriculadæ*, for besides *Melampus*, there are) 7 *Cassidula*, 2 *Plecotrema*, a *Pedipes*, *Marinula* and *Blauneria*, 10 *Scarabus* and 5 *Auricula*, 4 *Planorbis*, 14 *Physa*, 7 *Cyclophorus*, 11 *Hydrocena*, 7 *Truncatella*, 14 *Helicina*, 27 *Melanopsis*, 15 *Melania*, 47 *Neritina*, 11 *Navicella*. The only bivalve is a *Cyrena*.

The Viti or Fiji Islands furnish over 125 species, mostly of the same generic types as in New Caledonia, but the species of the terrestrial mollusks are all different. The genus *Omphalotropis*, however, is present, with 10 species; whilst *Melanopsis*, having 27 species in New Caledonia is here entirely unrepresented. There are 14 *Placostylus*, one of the sections of which, *Charis*, containing *P. fulguratus* and *malleatus*, is arboreal, living in the palms, bananas and *Pandanus*.

19. POLYNESIAN REGION.

Fischer has formed two principal groups of the islands of the Pacific, which he calls: 1, The Sandwich or *Achatinella* group; 2, The *Partula* group—comprehending all the other islands. The latter, however, he subdivides into the occidental islands, situated

north of the equator (Mariannes, Pelew, Carolines, etc.), and the austral islands, south of the equator (Samoa, Tonga, Cook, Tahiti, Paumotus, Gambier, etc.).

Throughout the entire region the terrestrial species are of small size; *Placostylus*, *Geotrochus* and *Cochlostyla* disappear. The heliciform shells belong to the genera *Patula*, *Endodonta*, *Trochomorpha*, *Nanina*, *Microcystis*, etc., whilst the operculated pulmonates are represented by *Diplommatina*, *Realia*, *Pupina*, *Helicina*. The terrestrial species are generally localized.

The Sandwich Islands. These contain nearly 400 nominal species, of which the three genera *Achatinella*, *Auriculella* and *Carelia*, closely related, are peculiar to this group. *Achatinella* alone has 288 species, or varieties, some of which are always dextral, others sinistral, and others again either dextral or sinistral. *Limnæa* is here sinistral. The progress of agriculture, disappearance of some of the indigenous trees, and introduction of cattle combine to diminish the *Achatinellæ*, some of the species of which are upon the verge of extinction.

The Partula Islands. In the Pelew Islands occurs a very curious fauna, characterized by numerous species of *Diplommatina* of the section *Palaina*. There are three *Partulas*.

The Mariannes or Ladrões contain 4 *Partulas*, etc. About twenty-five species, including a *Partula* inhabit the Carolines.

The Ellice and Samoa Islands appear to possess the same fauna, aggregating seventy-six species. The heliciform shells are of small size and belong to the genera *Nanina* (groups *Microcystis*, *Trochonanina*, *Gastrodonta*), *Patula* (*Endodonta*), *Trochomorpha*, etc. The genus *Partula* contains five species; there are four *Cyclophorus* (group *Ostodes*). The fresh-water shells include *Melania*, 11 sp., *Neritina* 13 sp., *Navicella*, 4 sp.

The Tonga Islands have about 50 species, a few of which are common to the Samoa and Viti Archipelagos. The Cook and Hervey Islands have 16 species of *Patula*, *Endodonta*, 3 of the curious genus *Diadema*, etc.

The Tahiti or Society Islands possess a very rich molluscan fauna, embracing 130 species. This is the metropolis of the genus *Partula*, which numbers 45 species here, besides the few found in other islands. There are 16 species of *Endodonta*, 10 of *Realia*, 10 of *Helicina*, 6 *Melania*, 7 *Neritina*, etc. Very little is known conchologically of the Paumotus and Gambier Islands, and not much more of the Marquesas; each of these groups contains a few *Partulas*.

20. NEW ZEALAND REGION.

Although the islands of New Zealand contain a large number of peculiar mollusks, there are generic analogies with Australia in the occurrence of *Paryphanta*, *Athoracophorus* and *Rhytida*,

and with New Caledonia in that of *Placostylus*, *Melanopsis* and *Rhytida*. The genus *Latia* is peculiar. The moist and equable climate of these islands, which have a mean temperature of 61° – 63° , is favorable to the existence of numerous land snails. The heliciform species number 58, whilst the operculates include only two *Cyclophorus*, a *Paxillus*, *Diplommatina*, *Realia*, etc. There is a *Physa* of the Australian group *Ameria*, 5 *Unionidæ*, and a *Potamopyrgus* or spiny *Hydrobia*, resembling West Indian and South American species. Hutton's catalogue of the land and fresh-water species, published in 1880, contains 128 names. The genus *Partula* is not represented. The Aucklands, Campbell, Norfolk and Kermadec Isles belong to this Province, but each contains one or more special species.

21. PATAGONIAN REGION.

Fischer very properly unites under this name the Argentine and Patagonian Regions of Woodward. The region is an extensive one, yet the fauna is very meagre, including only 174 species; 79 being terrestrial, of which not a single one is operculated. More than half the species are fluviatile. The physical condition of these countries explains the anomalous distribution of the mollusca. The pampas, or great plains of Patagonia, are dry and rainless nearly all the year; the vegetation which springs up during the light summer rains, becomes converted into natural hay for the support of the wild animals. In Fuegia the mean temperature is 33° – 50° , and there is rain and snow throughout the year; yet the bases of the mountains are clothed with forests of evergreen beech. The fertile portion of the Argentine States is separated from Bolivia by the wide plains of the Great Desert or northern prolongation of the pampas; and all the eastern part has been submerged at a recent geological period; the only promising districts are Paraguay and the eastern declivities of the Chilian Andes.

The characteristic terrestrial forms are *Bulimi*, with apertures contracted by teeth, sections *Plagiodontes*, *Odontostomus*, and *Macrodontes*; *Chilina*, a fresh-water pulmonate allied to *Limnæa*, but with toothed aperture, and peculiar to South America, furnishes 5 species; the bivalve genus *Monocondylæa*, also South American in distribution, has 5 species; there are 24 *Unio*, 17 *Anodonta*, and species of the related South American genera *Leila*, *Castalia*, *Mycetopus*, *Byssanodonta*. *Azara labiata*, an estuary shell related to *Corbula*, is found in the La Plata River. Of fresh-water gastropods, *Planorbis* has 6 sp., *Ampullaria* 9 sp., *Paludestrina* 11 sp. No *Melania* or *Paludina*. The Falkland Islands are 300 miles east of Patagonia. The only recorded shells are 2 species of *Paludestrina*. A single species, *Helix Hookeri* inhabits Kerguelen Island.

22. CHILIAN REGION.

The northern part of Chili belongs to the same physical region with Peru, consisting of dry and rainless plains. Here the land snails are few and small, and only seen after the dews. At Valparaiso rain is abundant during the three winter months, and the southern coasts are luxuriantly wooded and extremely wet. The fauna is characterized by the abundance of *Bulimi*, belonging to the sections *Borus*, *Scutalus*, *Peronæus*, and *Plectostylus*, all South American groups. There are but few *Helices*, one of which *H. laxata* attains a large size, and recalls by its form the *H. lanx* of Madagascar. There are only two operculated species. Among the fluviatile shells *Chilina* and *Unio* are largely represented. One of the former and a *Succinea* are peculiar to the island of Chiloe. The Islands of Juan Fernandez have a fauna completely restricted, numbering over 20 species, all terrestrial, mostly *Helix* and *Succinea*.

23. PERUVIAN REGION.

The long and narrow tract between the Andes and Pacific, extending from the equator to 25° S. lat. forms a distinct though comparatively unproductive province, including the coast of Ecuador, Peru and Bolivia. It is warm and almost rainless; the clouds discharge themselves on the east side of the Andes, and rain is so rare on the west coast that in some parts it only falls two or three times in a century. In Peru, during great part of the year, a vapor rises in the morning, called the "garua;" it disappears soon after midday, and is followed by heavy dews at night. There are a few helicoid shells, some of them of very peculiar appearance, but the *Bulimi* are predominant and include many species. The reappearance here of a group of the Mediterranean genus *Clausilia*, with 7 species, is a notable fact. There are 3 *Helicinas*. *Chilina* has disappeared, but there are 3 *Ampullaria*. *Planorbis* is well represented, as is *Anodonta*; besides which we find *Ancylus*, *Limnæa*, *Physa*, *Cyclas*, *Cyrena*.

The fauna and flora of the Galapagos Islands are peculiar, although related to those of South America. The only known shells are 18 species of *Bulimus*, forming the section *Nesiotes*; and of these, 10 species are restricted to single islands of the group.

24. COLUMBIAN REGION.

This includes the rainy and wooded States of New Granada and Ecuador (except the Pacific coast of the latter), the elevated and nearly rainless province of Venezuela, with a flora like that of the higher regions of the Andes; and Guiana, where the forests are most luxuriant, and rain falls almost daily (amounting to 100 or even 200 inches in the year). Most of the low lands, like

those of the Mexican Province, belong to the Cactus Region of botanists, and have a mean temperature of 68° to 84° . Land shells are abundant in the forests and underwood of the lower zone of the mountains, where the temperature is 10° less, and the rains more copious. These diverse countries are characterized by the abundance of bulimiform shells, *Bulimus*, *Bulimulus*, *Otostomus*, *Orthalicus*, etc.; of the operculated genus of *Cyclotus*, including some fine, large species, and of *Ampullaria*. The heliciform groups *Labyrinthus*, *Isomeria* and *Solaropsis* are numerous. Finally, the following characteristic genera occur: *Guestieria*, *Rhodea*, *Bourcieria*, *Mulleria*. The American *Clau-siliæ* are represented by a few species, but their metropolis is the Peruvian Region. There are a few *Streptaxis*—a Brazilian genus, several species of which, nevertheless, occur in the tropical countries of Asia and Africa. The genus *Mulleria*, which lives in the Rio Magdalena may be considered the analogue of the fresh-water oyster *Ætheria* of Africa. The Melanians mostly belong to *Hemisinus*, a South American group extending into Brazil, and having its northern limit in the West Indies.

25. BRAZILIAN REGION.

"The region of palms and melastomas," extending from the Amazon to the southern tropic, is one of the richest zoological provinces; it includes Brazil and the districts of Peru, Ecuador and Bolivia east of the Andes. A large part of the region is mountainous and rainy and densely wooded, but intersected by extensive plains (*Llanos*); some grassy and fertile, others dry, rocky and rainless—especially in the South. It is watered by numerous streams—the affluents of the Amazon and Plata.

The dominant character of the molluscan fauna is the importance of bulimiform snails, and the contrasting scarcity of the heliciform types; thus of about 300 species of terrestrial and fluviatile shells of the region, the *Bulimi* number 108, the *Helices* only 14. The principal forms are: *Streptaxis* 17 sp., *Anostoma* 4 sp.; *Helix*, of sections *Ophiogyra*, *Solaropsis*, *Geotrochus*, *Labyrinthus*; *Bulimus*, of sections *Macrodonates*, *Odontostomus*, *Tomigerus*, *Pelechilus*, *Anthinus*, *Pachyotus*, *Strophochilus*, *Borus*, *Orphnus*, *Otostomus*, *Liostracus*, *Anctus*, *Eudioptus*, *Rhinus*; *Peltella*; *Simpulopsis*; *Megaspira*; *Obeliscus*; *Dorissa*; *Hemisinus*; *Ampullaria*; *Hyria*; *Castalia*; *Leila*.

The interior streams contain but few gastropod mollusks. There are *Ancylus* 3, *Physa* 1, *Doryssa* 3, *Hemisinus* 17, *Melania* 6, *Ampullaria* 18, *Neritina* 2. The *Unionidæ*, etc., number nearly 50 species, including the South American genera *Hyria*, *Mycetopus*, *Castalia*, *Leila*, *Monocondylœa*. Besides the group *Borus*, containing the largest species of *Bulimi*, the other

Brazilian forms are those in which the aperture is dentate, angulated, or auriculiform.

26. MEXICAN REGION.

Includes the Republic of Mexico and Central America; Lower California also belongs to it zoologically. This extensive country comprises three physical regions; the comparatively rainless and treeless districts of the west; the mountains or high table-lands with their peculiar flora; and the rainy wooded region that borders the Caribbæan sea. It is divided by Fischer into four geographical subregions: 1. Subregion of the Gulf, comprising the coasts of the Gulf States (Tamaulipas, Vera Cruz, Tabasco, Campeche, Yucatan), the isthmus of Tehuantepec and Central America; 2. Subregion of the centre, formed of the temperate and cold districts (Puebla, Mexico, Zacatecas, etc.); 3. Subregion of the Pacific; 4. Subregion of Lower California.

The Subregion of the Gulf is characterized by the genera *Strebelia*, *Streptostyla*, *Petenia*, *Glandina*, *Xanthonyx*, *Helix* (groups *Odontura*, *Geotrochus*, *Corasia*), *Cœlocentrum*, *Eucalodium*, *Cylindrella*, *Macroceramus*, *Orthalicus*, *Bulimulus*, *Opeas*, *Spiraxis*, *Subulina*, *Vaginula*, *Aplecta*. All the Mexican operculated land snails inhabit this subregion: *Cyclotus*, *Cyclophorus*, *Tomocyclus*, *Choanopoma*, *Adamsiella*, *Tudora*, *Cistula*, *Chondropoma*, *Helicina* (36 species); as well as the genera *Ceres* and *Proserpinella* of the family *Proserpinidæ*: most of these genera are West Indian types. The Melanian genus *Pachycheilus* is peculiar to the region and its metropolis is Central America. A number of *Ampullaria* occur in the southern portion, as well as a single species of the South American genus *Hemisinus*, in Guatemala. There are numerous fine species of *Unionidæ* and a few *Cyrenidæ*.

The colder central region contains a very much less extensive fauna. There are a few *Glandina*, a *Helix* of the *Pomatia* section, *H. Humboldtiana*, and several small species of the *Polygyra* group; *Holospira* replaces the *Cylindrella* and *Eucalodium* of the warmer regions. A single Melanian, and a few *Physa*, *Limnæa* and *Planorbis* constitute the fluviatile gastropods.

The Pacific subregion is rather bare of mollusks also, but includes some characteristic fluviatile forms; the large *Aplecta aurantia*, the only North American *Corbicula*, 4 *Cyrena*, etc.

In Lower California the existence of 12 species of *Bulimulus* shows the affinity of the fauna with that of Mexico and of Western South America; on the other hand the *Helices*, few in number, are of Californian types. *Berendtia* is restricted to this subregion; the paucity of its species corresponds to the desert nature of its soil.

The Mexican fauna is characterized by the existence of num-

erous carnivorous land snails, nearly 100 species of which have been catalogued by Crosse and Fischer, an assemblage of agnathous gastropods nowhere else equaled. *Bulimulus* contains 74 species. The following genera are special to this province or have their metropolis here: *Strebelia*, *Glandina*, *Xanthyx*, *Cœlocentrum*, *Eucalodium*, *Holospira*, *Berendtia*, *Tomocyclus*, *Ceres*, *Proserpinella*.

27. CARIBBÆAN REGION.

The West Indian Islands offer the interesting spectacle of a succession of localized faunas of incomparable richness, occupying contiguous islands. The climate appears to be very favorable to the multiplication of snails, the mean temperature being 59° – 78° , the annual rain-fall usually over 100 inches. The most remarkable character of the mollusca of this region is the great proportion of pneumonopomata or operculated land shells, as well as the variety of generic types represented, some of which, such as *Geomelania*, *Chittya*, *Jamaicia*, *Licina*, *Choanopoma*, *Ctenopoma*, *Diplopoma*, *Stoastoma*, *Lucidella*, do not exist on the adjacent American continent. The operculated mollusks constitute one-half of the entire number of mollusca of Jamaica and Cuba, and a smaller, but relatively large proportion in the other islands.

A few West Indian shells are acclimated in the South of Florida, eighteen species occur in Mexico and Yucatan, and several are common to the Lesser Antilles and Venezuela; on the other hand several species of the surrounding faunas have been introduced, leaving the enormous number of 1200 or 1300 species, peculiar to the islands, many of which have an extremely limited area of distribution, being sometimes confined not only to a single island, but to a single valley, of the mountainous districts.

The West Indies may be grouped in accordance with the character of their faunas as follows: 1, Bahamas; 2, Cuba and Isle of Pines; 3, Jamaica; 4, Haiti and Navassa; 5, Porto-Rico, Viéque, St. Croix, St. Thomas, St. Johns, Tortola, Anguilla, St. Martin, St. Bartholomew, Sombbrero; 6, Guadeloupe, Martinique, Dominica, St. Christopher, Antigua; 7, St. Vincent, St. Lucia, Barbados, Grenada, Trinidad; 8, Windward Islands, Curaçoa, Buen-Ayre.

This grouping mainly corresponds with the depth of the surrounding water, those islands which partake of a common fauna being generally separated by water of no great depth, so that at some former period of the world's history they may have been connected or at least approximated more closely than at present. —BLAND, *Proc. Am. Philos. Soc.*, xii, 56.

1. *Bahamas*. Out of 43 species, 29 are restricted to this archipelago, including all the operculates. The continental

genus *Schasicheila* has a single species, and is nowhere else represented in the West Indies. The Caribbæan group *Strophia* of Pupa has 8 species.

2. *Cuba and Isle of Pines.* More than 600 species have been described, of which 250 species are operculates. These are all, with the trifling exception of 53, confined to the island; all the operculates except the *Truncatellæ* are thus restricted. The dominant genera are: *Strophia* (19 out of 36 known species), *Macroceramus* (31 out of 51), *Cylindrella* (93 out of 140), *Megalomastoma* (12 out of 29), *Chondropoma* (51 out of 100), *Cistula* (15 out of 42), *Ctenopoma* (23 out of 26). There are also 17 species of *Glandina*, 76 of *Helix* (largely of special groups,) 30 of *Stenogyridæ*, 10 of *Succinea*, 78 of *Helicinidæ*, etc. Fresh-water shells, as in the other islands, are scarce; there are 39 gastropods, 6 lamellibranchiates, including the only two species of *Unio* in the West Indies.

3. *Jamaica.* This island is almost as rich in mollusks as Cuba, containing 500 species, nearly half of which are operculates. The genera *Geomelania*, *Chittya* and *Jamaicia* are peculiar to the island, and *Stoastoma* and *Lucidella* each have only a single extra-limital species. The other characteristic mollusks are: *Adamsiella* (12 out of 17 known species), *Tudora* (17 out of 33), *Helices*, nearly 100 species (including the groups *Sagda*, *Pleurodonta*, *Caracolla*, *Dentellaria*), the groups *Lia* and *Casta* of *Cylindrella*, numerous *Cyclotus*, etc. The genera *Strophia* (Pupa), *Licina* and *Magalomastoma* found in Cuba are not here represented. Only 41 Jamaica species occur in other localities.

4. *Haiti and Navassa.* Haiti has about 200 species, of which 70 are operculated, and 2 (*Planorbis*) fluviatile. The island has not been so thoroughly explored for mollusks as either Cuba or Jamaica, and will probably yield much richer results than those already recorded. There are no restricted genera, but those most largely developed are: *Glandina*, etc., 10, *Helix* 43, *Macroceramus* 10, *Cylindrella* 30, *Stenogyra* 12, *Choanopoma* 12, *Helicinidæ* 29. There is a single species of the Jamaica group *Lia*.

The guano island of Navassa has so far furnished only three species, all peculiar.

5. *Porto Rico, and neighboring Islands.* About 120 species are recorded; among them the genus *Gæotis* is restricted to Porto Rico, where lives also the only West Indian *Clausilia*, of the group *Nenia*. The operculates are less developed in this island than elsewhere, the genera *Tudora*, *Cyclostoma*, *Ctenopoma*, *Geomelania*, *Jamaicia*, *Adamsiella*, *Lucidella*, *Diplopoma* and *Trochatella* being absent.

6. *Guadeloupe, Martinique and neighboring Islands.* The characteristic group is *Dentellaria* (*Helix*), several species of

which have a somewhat extensive distribution. Gaudeloupe has 68 species, Dominica 20, St. Kitts 6, Martinique 50, etc. *Amphibulina patula* appears to have become extinct a few years since in Guadeloupe, but still lives in Dominica and St. Kitts.

7. *St. Lucia, St. Vincent, Barbados, Grenada, Tobago, Trinidad.* These islands differ radically from those which precede them by the introduction of South American Bulimi. This continental character is more pronounced in the islands nearest the Venezuelan coast. (The characteristic Bulimi of the other islands are of very few species, but two or three of them have a much more extensive distribution than the other land shells.) There are at St. Lucia, 3 species, at St. Vincent 15, at Barbados 30, at Grenada 14, at Tobago 1, at Trinidad 52. In the latter island, nearly half of the species are of continental, principally Venezuelan origin, including the large *Bulimus (Borus) oblongus*, *Ceratodes (Ampullaria) cornu-arietis*, *Streptaxis deformis*, etc. Here is found the only West Indian species of Anodonta.

8. *Windward Islands.* Very few species are known: the curious genus *Ravenia* is special to the islet Los Roques.

The distribution of the West Indian shells presents some interesting peculiarities. Thus the group *Strophia* lives only in the Bahamas, Cuba, Haiti, Porto Rico, St. Croix and Curaçoa, not in the intermediate islands; *Simpulopsis* has been found at Haiti, Porto Rico and Trinidad; *Amphibulina* occurs only in the Lesser Antilles; *Stoastoma*, *Trochatella*, *Lucidella*, *Proserpina*, *Ctenopoma*, on the contrary, are restricted to the Greater Antilles; *Gundlachia* has only been found in Cuba and Trinidad; *Cylindrella*, *Bulimulus*, *Glandina*, *Macroceramus*, *Helicina*, *Cistula*, *Chondropoma*, *Choanopoma* and *Tudora* are found in nearly all the islands; there are only 3 Unionidæ, 2 of them restricted to Cuba, the other to Trinidad.

28. AMERICAN REGION.

The eastern and central portions of the United States constitute a vast and thickly populated molluscan region: Florida, Louisiana and Texas are included in it, although a few of the species are derived from the neighboring Mexican and Caribbean faunas.

Woodward and Binney have divided this region into provinces which, I perfectly agree with Dr. Fischer, have very slight claims to recognition from any peculiarities of their several faunas; whilst the region as a whole certainly presents a large assemblage of forms originating within, and in many cases confined to its boundaries. The Helices are not very numerous, and, in contradistinction to those of Europe and of California are mainly unicolored shells. A large proportion of them are with toothed aperture. The following are peculiarly American groups; Mesomphix,

Gastrodonta, Helicodiscus, Polygyra, Stenotrema, Triodopsis, Mesodon, etc. Yet few as the Helices are, they outnumber the Bulimi and Pupæ, which are mostly minute, and also unicolored. Succinea is well developed, and there are a few slugs. Only two species of operculates are native to the region.* On the other hand the development of the fluviatile forms is enormous, and is unequalled in any other region. The numerous large rivers and lakes are not only well populated, but in many cases each river system has forms restricted to itself.

The so-called American Melanians belong to a group entirely restricted to the United States, and form a distinct family, Strepomatidæ. The animal differs from the true or oriental Melanians by the absence of a fringed border on the mantle and by their oviparous reproduction. In 1875, I published a monograph of the Strepomatidæ, containing nearly 450 species after making wholesale reductions on the number of described species. Since the preparation of that monograph, a few additional forms have been characterized. The family includes 9 generic groups: *Io* 3 species, *Pleurocera* 83, *Angitrema* 12, *Lithasia* 13, *Strophobasis* 9, *Eurycælon* 10, *Goniobasis* 255, *Schizostoma* 28, *Anculosa* 31. Most of these are Southern species, the Alabama River and its tributaries, the Coosa and Black Warrior, being the most thickly and variously populated. The waters of the N. England, Middle and Northwestern States contain but few species, yet those which occur have usually a much more extended distribution than the Southern species. The genus *Io* is entirely confined to the Tennessee River and its tributary streams, the genus *Schizostoma* to the Coosa River. Few of these shells occur west of the Mississippi River. The development of Naiades is equally extraordinary with that of the Strepomatidæ. Mr. Lea, who has for half a century devoted unceasing attention to this very difficult family, admits 645 American species, of which are *Unio* 559, *Margaritana* 28, *Anodonta* 58; most of them first characterized by himself. The distribution of the Unionidæ does not differ much from that of the Melanians; where the latter are most plentiful, the former also abound.

Limnæidæ and Viviparidæ are both largely developed; the species of the first family are particularly numerous, but so polymorphous that it is very difficult to define the species. The American Viviparidæ include the special types *Tulotoma*, and *Lioplax*. The European Paludina is represented by *P. lineata*, a species which has been considered identical with its

*The limits of this work forbid pursuing more in detail the geographical distribution of American terrestrial mollusks: a valuable paper upon this subject by Mr. Wm. G. Binney, is contained in Bull. Mus. Comp. Zoology, iv, 17.

European analogue, *P. vivipara*, but which differs in possessing four colored bands, whilst the latter has but three. Several species of *Limnæa* and *Planorbis* are identical with European and Siberian species, so that these species have a wide distribution. One of the *Unionidæ* also, the *Margaritana margaritifera* occurs in all the colder waters of N. America, as well as in Europe and Siberia.

There are, in the United States, 2 species of *Cyrena*, numerous *Cyclas* and *Pisidium*, and the peculiar genus *Rangia* or *Gnathodon*, which inhabits the lagoons of the Gulf States.

The prodigious multiplicity of individuals of the fresh-water species is a fact as remarkable as the quantity of specific forms. The bottoms of some lakes are formed of such thick deposits of shells that they are gathered for agricultural top-dressing. At Muscle Shoals on the Tennessee River, navigation is actually impeded by the accumulation of *Unionidæ*. The city of Mobile, Alabama, is built upon a bank of *Rangia*; the road from New Orleans to Lake Pontchartrain, 6 miles long, is constructed of *Rangia* shells found at the eastern extremity of the lake, where the bed of shells measures a mile in length, by 200 feet wide, with a depth or thickness of 15 feet.

Fischer includes the Bermudas in the American rather than in the West Indian region, distinguishing it from the latter by the absence of *Cyclostomidæ* or operculated land shells. Only 19 species are known, 9 of which are West Indian and 2 European, the rest peculiar. 6 of these species occur in Texas and Florida but may be considered as acclimatized rather than native forms.

29. CALIFORNIAN REGION.

The Pacific slope from Alaska to San Diego is inhabited by a fauna very distinct from that of the American Region. The *Helices* are highly colored, and more like the European groups and are numerous—principally *Arionta*, *Aglaja*, *Selenites*. The *Unionidæ* and *Melanians* are very rare, but fresh-water pulmonates abound, and some of them are of Eastern American species. There are no operculated land shells. The principal genera, besides those already enumerated, are *Prophysaon*, *Ariolimax*, *Binneya*, *Hemphillia*, *Pompholyx*, *Carinfex*, *Tryonia*, *Cochliopa*, *Fluminicola*. The *Tryonia* are all dead shells, occurring numerously upon the surface of the ground in the Colorado Desert. Similar shells are found living in Lake Baikal, Siberia.

30. CANADIAN REGION.

Fischer has constituted this region for British America, Alaska, Greenland and a part of New England, and states that it is characterized by a mixture of American and European forms. He has divided it into 5 subregions.

I think that this should be considered rather as a portion of the American region, as it has no faunal peculiarities whatever. Many of the species, especially in the northern portions of the territory, are identical with European species, but then a considerable number of them are known to occur in North Asia also; they are, in fact, circumboreal. There are a few peculiar species, principally in Greenland and Iceland; both land and fresh-water shells being included in these, but no Melanian or Unio.

The question of the direction whence species common to the old world have been introduced into America, has not been decided, although, with the increase of our knowledge of Asiatic localities and species, it is becoming more probable that such forms have usually come thence. This view is strengthened by the occurrence of representatives of some of the Californian fluviatile forms in Lake Baikal. On the other hand, the ancient intercourse of Europe with Iceland, Greenland, New England, etc., cannot have failed to introduce accidentally a crowd of species; some of which, indeed, are known to have spread rapidly within a short period. Thus, the great snail, *Limax maximus*, has within a very few years spread from Philadelphia, where it first became acclimated in cellars, to New York and other cities; adopting subterranean habits in this country rather than inhabiting the surface of the earth, where the atmosphere would be too dry for its existence; it is now a commonly occurring species. Identical species may have been introduced both from the West and East, if of decidedly European type, but there are species, as the Limnæans, for example, which may as well have originated here and thence spread to the old world. Finally, we do not know that identity of specific or structural character is conclusive as to identity of origin.

HYPSOMETRICAL DISTRIBUTION OF LAND AND FRESH-WATER MOLLUSKS.

Mollusks are subject to conditions of existence varying according to altitude. As plants change according as they are submitted to the changing climates of different elevations, so shells are necessarily subject to like influence, some species never ascending beyond a certain height, others living entirely in mountainous regions. Whilst in Europe the elevation beyond which mollusks cannot exist is about 8000 feet, in America and Asia they are collected at nearly double that altitude.

In examining the mollusks of the Pyrenees, the Alps and Auvergne, the following are the results reached:

1. Lower Valleys. From the sea level to 3000 feet altitude

mollusks are very numerous, the fluviatile genera being entirely confined within this limit.

2. From 3000 to 4500 feet. This is the greatest height attained by a number of species of *Helix*, *Hyalina*, *Vitrina*, *Pupa*, *Clausilia*, etc.; some of which are found also in the lower valleys.

3. From 4500 to 6000 feet. Fischer has called this the zone of *Helix memoralis*, which occurs no higher, and which is found on rocks and wooded heights. In the Alps the same mollusks occur at a greater altitude than in the Pyrenees and Auvergne: thus *Helix arbustorum*, *hispida*, *Hyalina diaphana*, *Cionella lubrica*, having their upper limit within this zone in the Alps, in the other regions do not attain beyond 3000 to 4500 feet.

4. From 6000 to 8000 feet. The number of mollusks is much reduced, the species decidedly Alpine in character. The relation between the distribution of terrestrial mollusca and that of the plants on which they feed, is of course very intimate; thus in the Higher Kabylia, Aucapitaine's observations have resulted in establishing three zones of distribution for mollusks, namely: 1, that of the ashes, olives and pomegranates (450 to 2100 feet); 2, that of the oaks and pines (2100 to 3600 feet); 3, that of the cedars and green turf (3600 to 7200 feet). At Guadeloupe, West Indies, *Succinea Sagra* and *Homalonyx unguis* are found on the lowest lands; *Stenogyra octona*, *Leptinaria lamellata*, *Opeas Caraccasensis* occur no higher than 250 to 300 feet; *Bulimus exilis*, 600 feet; *Helix lychnuchus*, *dentiens*, *Josephinæ*, *pachygastra*, occur in forests at 900 to 1200 feet; *Pellicula appendiculata* lives in the region of palms, between 1800 and 2100 feet; *Bulimus limnoides* and *chrysalis* are abundant between 2000 and 2500 feet among roots; finally *Bulimulus Lherminieri* exceeds 2500 feet.

Arthur Morelet has established five molluscos zones for Peru and Bolivia, as follows: 1, Maritime Region, up to 2000 feet; 2, Region of the Montaña, from 2000 to 5000 feet; 3, Temperate Region, from 5000 to 8000 feet; 4, Cold Region, from 8000 to 12,000 feet; 5, Icy Region, from 12,000 to 16,000 feet. Within this latter region occur the following: *Limax Andecolus*, *Bulimus culmineus*, *B. nivalis*, *B. ochraceus*, *B. Yanamensis*, *B. Weddelli*, *Pupa Paradesi*, *Planorbis montanus*, *P. Andecolus*, *Paludestrina Andecola*, *P. culminea*, *Cyclas Forbesi*. The fluviatile mollusks enumerated occur in Lake Titicaca, the altitude of which is nearly 13,000 feet.

Mexico may be divided into three zones: 1, Tropical, up to 2500 feet; 2, Temperate, 2500 to 5000 or 6000 feet; 3, Cold. Among the species of the cold zone are: *Bulimulus Ghiesbreghti*, *B. sulcosus*, *Helix Humboldtiana*, *Glandina coronata*, *G. Orizabæ*, *Planorbis tenuis*, *Limnæa attenuata*. The two latter inhabit the Lake of Mexico, at over 7000 feet altitude.

A few Asiatic species have been collected at great heights.

Helix (Plectopylis) Shiroiensis, over 9000 feet. India.

Buliminus vibex, 7000 feet. India.

Buliminus nivicola, 14,000 feet. India.

Buliminus ornatus, 14,000 feet. India.

Nanina liratula, 6000 feet. Ceylon.

Stenogyra latebricola, 7000 feet. Landoura, Bengal.

Limnæa Hookeri, 18,000 feet! Landoura, Bengal.

Anadenus Schlagintweiti, 16,500 feet. India.

In Polynesia, *Helix bursatella*, a small species, lives at Tahiti between 2000 and 5000 feet altitude.

In examining the faunas of distant mountainous regions of Europe, we find identical or representative species, which, nevertheless do not occur in the intervening plains: for example, *Pupa megacheilos*, Italy and Pyrenees. *Helix arbustorum*, Alps; and *H. Xatartii*, Pyrenees. *Helix ciliata*, Alps; and *H. Becarii*, Abyssinia. On the other hand some of the mollusks of cold countries are found also in more southern regions, but at a greater elevation, so that the conditions of temperature and of vegetation are reproduced; thus *Vertigo alpestris* inhabits Scandinavia, and occurs again, upon the Alps only, in Switzerland.

These facts have a great importance in connection with a just appreciation of the physiognomy of the quaternary fauna of a determined region.

As to the bathymetrical distribution of lacustrine mollusks, we know absolutely very little. The Lake of Geneva has a maximum depth of 1100 feet, with a uniform and constant temperature at all depths. Some crustaceans found at the bottom of the lake are blind, but the Limnæans have their eyes normally pigmented. Forel says: The deep fauna of the lake consists of a few species belonging to the most of the classes of animals inhabiting fresh water. A certain number of genera and families represented in the littoral fauna appear to be wanting to the abyssal; but there are no generic types belonging exclusively to the latter. Some species of the abyssal fauna, however, are different but analogous to superficial forms—differences which may be attributed to adaptation. Forel and Brot state that the pulmonary chamber of *Limnæa abyssicola* contains no air at the moment when it is taken from the water; but preserved in a jar, the animal behaves like its congeners, coming to the surface to respire, and passing entire hours out of the water. The abyssal Pisidiums of the Lake of Geneva and of other Swiss lakes have the following characters in common, their minute size and enlarged beaks, characters which are similar to *P. abyssicola* of Lake Superior.

In Lake Baikal remarkable results have been obtained by an exploration of its depths, in making known fauna essentially different from that of the surface. Messrs. Dybowski and Godlewski obtained at or within 10 mètres of the surface, the following species: *Valvata Baicalensis*, *V. Grubii*, *Baicalia Angarensis*, *B. elata*, *Choanomphalus valvatoides*, *C. Schrencki*, *Ancylus Sibiricus*, *A. Troscheli*, *Unio* sp.

Between 10 and 100 mètres they dredged *Hydrobia Martensiana* and *H. maxima*. Commencing with 100 mètres *Choanomphalus Maacki* was found. Finally, between 300 and 350 mètres were obtained the following strange forms: *Choanomphalus Maacki*, *Baicalia pulla*, *Godlewskia turriiformis*, *Trachybaicalia carinato-costata*, *T. costata*, *T. carinata*, *T. contabulata*, *T. Wrzesnowski*, *Dybowskia ciliata*, *D. Duthiersi*. Curiously enough, some of these exclusively deep-water forms are closely related to the fossilized shells of the genus *Tryonia*, occurring in countless myriads on the surface of the dried basin of the Colorado Desert of North America.

List of important recent works and papers upon the geographical distribution of the mollusca.

No attempt has been made to render the following list complete; only some of the most useful or recent publications upon each fauna are enumerated. Woodward's and Fischer's "Manuals," both contain many lists of species characteristic of the various geographical provinces: these may be consulted with advantage by those who are acquainted with the species; to others they are simply names without import.

MARINE PROVINCES.

I. *Arctic Province*:—

Sars. *Mollusca regionis articae Norvegiæ*. Christiania, 1878.

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Küster. Systematischen Conchylien Cabinet. 320 parts, 4to. This grand work, in course of publication for nearly fifty years, approaches completion. It contains over 1800 beautifully executed colored plates. The more recent monographs are carefully prepared by such specialists as Kobelt, Weinkauff, Pfeiffer, Philippi, Dunker, Römer, Clessin, Brot and von Martens. Importation cost, about six hundred and fifty dollars.

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DISTRIBUTION OF THE MOLLUSCA IN TIME.

The brevity and excellence of the remarks of Dr. Paul Fischer upon the distribution in time of fossil mollusca, is my sufficient apology for transferring them almost bodily to these pages, distinguishing them throughout by quotation-marks: they constitute a most valuable portion of his excellent "Manuel de Conchyliologie."

"Fossils, considered at first," says Fischer, "as *lusus naturæ* or as the remains of animals like those which now people our seas and continents, commenced to be differentiated from living forms towards the close of the last century. Buffon sustained this opinion strenuously: 'The knowledge of all the petrifications, of which we no longer find living analogues, requires lengthened study, and the thoughtful comparison of all the species of petrifications which have been found so far in the bowels of the earth, and this science is not yet far advanced; nevertheless we are certain that there are several species such as the Ammonites, the Orthoceratites, the Belemnites, etc., to which no existing species can be referred. * * * Their petrification is the great means by which nature has preserved forever the record of perishable beings; it is in fact by these that we recognize the most ancient productions and that we have an idea of these *species now annihilated*, the existence of which has preceded that of all living and growing objects; *they are the sole monuments of the earlier ages of the world; their form is an authentic inscription, which it is easy to read in comparing them with similar organized bodies.* * * * It is above all among shells and fishes, the first inhabitants of the globe, that we can count a very large number of species which no longer subsist; I will not undertake their enumeration here, which, although lengthy, would be still incomplete; such a work upon ancient nature would alone require more time than yet remains to my life, and I can only recommend it to posterity.'

"This passage indicates clearly that Buffon already considered fossils as a means of establishing the chronology of stratified rocks. In the inquiry which he indicated, Cuvier and A. Brongniart in France, and W. Smith in England, almost simultaneously engaged. The two former, in 1808, remarked that the fossils distributed in each bed generally remain the same throughout its extent, but differ in passing from one bed to another. This character serves to distinguish the beds, and to recognize their recurrence at distant localities. 'This is a mark of recognition,' they say, 'which so far has never failed us.'

"A. Brongniart is still more explicit in 1822: 'In order to characterize the strata, one must not only designate the species found in them, but designate them all, determine them very

exactly, so as not to give the same name to bodies which, having apparent resemblances, are nevertheless distinct species, although closely related. Such is the important connection of zoology with geology. It is by this double consideration that we shall attain the aim of the latter science, which is the exact knowledge of the relative antiquity of the beds which form the shell of the globe.'

"The views of William Smith are not less pointed: 'Organized fossils are to the naturalist as coins to the antiquary; they are the antiquities of the earth; and very distinctly show its gradual, regular formation, with the various changes of inhabitants in the watery element.'

"Whilst modern geologists recognize all the great principles established by Buffon, Cuvier, Brongniart and Smith, they vary in the interpretation of the laws of succession of living beings upon the surface of the earth.

"One school, which has had for its chiefs A. d'Orbigny and Louis Agassiz, and which has perhaps borrowed from Cuvier the basis of the doctrine, admits that living nature has been renewed a great number of times, without the beings of one period being able to perpetuate their specific existence into the succeeding period. Consequently each period preserves for us the remains of a special creation, terminated by a general cataclysm. Such is the theory of successive creations, which has ruled during about a quarter-century and which has given a remarkable impulse to palæontology.

"In the opposing school, to which are attached the names of Brocchi, Constant Prevost, Boué, Lyell, d'Archiac, Gaudry, Tournouër, and which, in certain points of view, approaches the theories of Lamarck, of Geoffroy Saint-Hilaire and of Darwin, great cataclysms no longer exist as the general cause of the destruction of life; their influence is purely local; life has never been interrupted, although modified during the series of ages.

"In the appreciation of the fossils these two schools arrive at nearly identical conclusions. For the school of multiple creations, the fossil serves to characterize a period; for the developmental school, the fossil, by its more or less advanced state of evolution, takes the place of a chronometer for judging the antiquity of the beds where it has been discovered. Whatever may be the theory, it is admitted then as demonstrated, that each period of life on the surface of the earth has been characterized by living beings, the ensemble of which has differed from that of the preceding and subsequent periods. Each fossiliferous bed of importance may practically be considered as representing a distinct creation; consequently each period has its peculiar fossils."

* A circumstance which gives to fossils a great importance as

characteristic of beds, is that their occurrence is never repeated. They become extinct or modified. "One of the proofs that species are extinct consists in the fact that they have been replaced by other species having filled the same functions and found in deposits formed under similar conditions" (Forbes).

"These ideas have been combatted by the advocates of the doctrine of colonies, who admit the reappearance of species after the lapse of a period more or less long, and at different levels. But folds, dislocations and faults may simulate the reappearance of an identical fauna. In this case, colonies would be, as d'Archiac has written, only stratigraphical illusions, resulting from an incomplete appreciation of facts, judged by deceptive appearances. 'From the moment when a type has appeared for the first time, to the moment when it has entirely disappeared, there has never been an interruption in its existence'" (Pictet).

The very ancient and nearly extinct order of tetrabranchiate cephalopods has been the subject of much discussion between the creative and development schools of naturalists, and may be conveniently adduced for the purpose of exhibiting their respective lines of argument. This work would be enlarged to undue proportions were I to attempt to discuss the subject at length: a few pages extracted from Vol. I of my "Manual of Conchology" will give an idea of it:

Mr. Alpheus Hyatt has remarked that the young of all the coiled cephalopods start with a straight or bent cone, and begin their coil abruptly, always leaving an opening in the umbilicus through the centre of the first whorl. The development of the Nautiloids, in time, is also marked by a gradual involution from the perfectly straight *Orthoceras* to the *Nautilus Pompilius*, where the expansion of the last whorl conceals the umbilicus. The progress of the Ammonoids, on the other hand, is marked by the gradual uncoiling of the shell, ending with the straight *Baculites* of the cretaceous; this feature is, therefore, of great importance in a natural classification of these groups.*

Mr. Hyatt has also carefully studied the embryology of the shell of the fossil cephalopoda; and in a richly illustrated memoir, published by the Museum of Comparative Zoology, at Cambridge, Mass., he attempts to prove the development theory by the results of these studies.

M. Joachim Barrande, however, who is the most distinguished of living authorities upon the fossil cephalopods, differs in toto from Mr. Hyatt's decisions. He has published (in 1877) "*Etudes Générales*," in which he devotes over two hundred octavo pages to a careful review of the entire subject, and reaches the following conclusions:

* *Proc. Bost. Soc. N. H.*, xii, 216, 1868.

I. *Generic Types.*

1. Absence of cephalopods in the primordial silurian fauna of all the countries where it has been ascertained to exist; that is to say in about 25 natural basins, largely spread over the two continents. This absence is in harmony with that of the acephala and the rarity of gasteropoda and heteropoda in the same fauna. It is inexplicable by the theories of evolution.
2. Sudden appearance of 12 types of cephalopods in the first aspect of the second Silurian fauna.

This sudden appearance is as inexplicable as their total absence in the primordial fauna. This number, 12, constitutes nearly half of the 26 types admitted in his studies, among the 3 families: Nautilidæ, Ascoceratidæ and Goniatidæ.

3. The 12 primitive types show, in their earliest species, the contrast and plenitude of their characters.

This plenitude and this contrast are above all remarkable in two straight types: Orthoceras and Bathmoceras. One sees also in some species the maximum of the size known, as in *Naut. ferox* Bill. of Canada. The plenitude of typical characters and the size not surpassed by later appearing species, are in disaccordance with the slow and successive progress attributed to evolution.

4. The 12 primitive types are very unequally distributed in the palæozoic countries. This distribution indicates no centre of diffusion, no point of departure for evolution.
5. Among the 12 primitive types, are found those the most contrasted in form and structure. Ex.:

Orthoceras, with straight shell.

Cyrtoceras, with curved shell.

Nautilus, completely spiral in the same plane.

Trochoceras, doubly spiral.

Bathmoceras, shell straight, but characterized by an obsolete siphon.

In order to derive from a common ancestor types so much differentiated, one must have an indefinite number of generations and of transition-forms, of which there remain no trace whatever.

6. The 14 types posterior to the 12 primitive types, also appeared as suddenly, without being announced by any transition-form, as for example: Ascoceras and Goniatites. One can apply to them also the preceding observation.
7. The vertical position of the 26 types in respect to their first appearance, offers a combination the most opposed to evolution, for instead of showing a successive progress in the number of first appearances, it presents a rapid diminution thereof. In fact:

16 of these 26 first appearances (comprising the 12 primitive types) are found within the limits of the 2d fauna.

8 in the limits of the 3d fauna.

1 towards the end of the Devonian fauna.

1 during the Eocene period.

8. This diminution of the apparitions of generic types is in disaccordance with the increase of the number of species during the Silurian period.

In effect, if the new types were formed by the divergence of the species, as supposed by the development theory, the increase of the number of specific forms must entail an increase of the number of generic types. In any case it could not cause a diminution of them.

Then, each of the principal facts that we have given on the subject of generic types, constitutes a grave discordance between the theories of evolution and the reality.

II. *Specific Forms.*

1. We have never acquired the certainty and we have never been induced to suppose that any species among the cephalopods of Bohemia was derived by filiation and transformation from another anterior species. The filiation and transformation are then, in our point of view simply theoretic fictions.
2. No species, to our knowledge, has been transformed to a new generic type, neither by successive slow variations nor by sudden changes.

On the contrary we have ascertained at various times that all the species and all the groups of the congeneric forms, which have varied sensibly from their generic type in certain particulars and which appeared to tend towards a new type, appeared and disappeared suddenly, without leaving any posterity preserving the traces of the same character.

3. Our second phase of Fauna No. 3 possesses alone 777 species of cephalopods, that is to say about 31 per cent. of all the species of this order known in the Silurian. Our basin, very remarkable for its small size furnishes about 45 per cent. of these.

These accumulations of cephalopods in surfaces so restricted are in contradiction with the theories of natural selection and of the struggle for existence.

III. *Elements of the Shell.*

The particular study of each of the elements of the shell of the cephalopods, of which we have presented a resumé, shows that none of them have followed a gradual variation in any one direction. On the contrary, we have observed the stability of

these elements, notwithstanding their specific and temporary variations. These facts are manifested above all in the genera of which the duration has been the longest, as *Orthoceras* and *Nautilus*.

IV. *Stability of the Genera.*

1. *Orthoceras* takes the second rank, by its longevity, among the generic types, but the first by its richness in species, since it furnished alone about half those of the Palæozoic cephalopods. It traverses every age, commencing with the origin of the second fauna, to the extinction of the Triassic fauna. Its species, very diverse in every horizon, preserve nevertheless their typical features very plainly, in about 1146 forms enumerated in our studies.

Among the proofs of the stability of the elements of the shell in this genus, we have observed a very remarkable and probably unique fact in palæontology. It is that on Plate 1, of Dr. V. Mojsisovics' "*Das Gebirge um Hallstatt*," is shown seven species of Triassic *Orthoceras*, which could be intercalated among the plates representing the Silurian species of our fauna No. 3, without any man of science supposing that he saw the last remains of that type. In fact, they are hardly distinct from the species which characterized the epoch of the most luxuriant vitality of the genus.

2. *Nautilus* has enjoyed the privilege of an incomparable duration, from the first appearance of cephalopods, at the origin of the second Silurian fauna to the present time. The succession of its species has traversed every geological age, and if it had been subjected to the supposed influences of evolution, it would show us a series of transformations or of progressions which, accumulating, would far remove the present from the primitive forms. We do not see why these extreme forms arising during the existence of *Nautilus* should not contrast among themselves like those of the *Amphioxus* and of *Homo sapiens*, between which imaginary evolution has worked, according to theory, in nearly the same period of time.

But the material facts discovered by palæontology and accessible to every one, dispel all illusion. In effect, the Nautilides, notwithstanding the great number of their specific forms, which must exceed 300, depart so little from their initial type, throughout the geological ages, that the merest novice would not hesitate in any case to recognize their generic nature. The variations or differences among the species, oscillate without any tendency to continue in a single direction so as to found a new type. In the actual fauna, *Nautilus* does not show, between its forms and the primitive forms, any greater differences than those which all naturalists

agree in considering as purely specific. Even the Triassic Nautilides show less affinity to existing species than do the primitive forms. The theoretical evolution of the cephalopods, like that of the Trilobites, appears to us to be imaginary, without any foundation in fact.*

Dr. Paul Fischer, in a notice of Barrande's work, whilst acknowledging the strength of the facts and observations brought forward by that distinguished palæontologist against the development theory, does not consider them conclusive: The type *Goniatites*, says M. Fischer, has always been considered by evolutionists as a natural transition between the *Nautilus* with its very simple partitions and the foliaceous sutures of the *Ammonite*; an opinion which is strengthened by the appearance of *Goniatites* chronologically intermediate between the other two. In order to show the extreme difference which exists between the *Nautilus* and the *Goniatites*, M. Barrande has studied the characters of the initial shell in these two genera—a study which has acquired great importance since the publication of Mr. Alpheus Hyatt's "*Fossil Cephalopoda*."

Mr. Hyatt has shown that the initial chamber of *Nautilus Pompilius* shows an elongated nearly linear cicatrice, enclosed by an elliptical surface slightly depressed. He supposes that the ovisack was attached to the elliptic surface, and that the cicatrice is the vestige of an opening which placed this ovisack in communication with the initial air-chamber of the shell; but he has never seen this supposed ovisack, which is hypothetical. For him, the *Nautilus* is a cephalopod which has lost its ovisack.

In *Ammonites* and *Goniatites* the initial disposition is entirely different. The ovisack is plainly visible, globular or ellipsoidal, more dilated than the part contiguous to the chambered spire. No appearance of a cicatrice. It suffices, consequently, to examine the first chamber of a cephalopod to class it among the *Nautilides* or the *Ammonides* and *Goniatides*.

M. Barrande has shown that the initial appearance of the shell of *Nautilus* is exhibited without any change through all the geological periods to the present time. The fissure is supposed by M. Barrande to have placed the mollusk contained in the initial chamber in communication with a transitory organ, either a vitelline vesicle (which, to M. Fischer, appears inadmissible) or to a natatory bladder, etc.

From the first appearance to the final extinction of the *Goniatidæ* and *Ammonitidæ*, they always show a typical ovisack; it is therefore impossible to derive them from the *Nautilidæ*, as supposed by some developmentalists. This difference has induced M. Munier-Chalmas (*Comptes Rendus*, Dec. 29th, 1873) to

* "*Céphalopodes, Etudes Générales*," 224-230, 1877.

separate the two former from the tetrabranchiate or tentaculiferous Cephalopoda (Nautilidæ), and to unite them with the dibranchiate or acetabuliferous group (Spirulidæ and Belemnitidæ), which are provided with an ovisack.

It still remains to ascertain whether the presence or absence of the ovisack has the systematic importance attributed to it; what is its nature and what is the purpose of the cicatrice. The word ovisack may be badly chosen because it supposes the existence of calcareous envelopes to the eggs.

One might discuss and wonder a long time on this subject until a direct observation on the embryogeny of Nautilus shall give us the true solution. It is thus that the question of the parasitism of the Poulpe of the Argonaut was agitated with ardor until the day that Duvernoy showed the embryo of Argonaut to be provided with a shell in the egg.

M. Fischer concludes, "Is the doctrine of evolution overthrown by the facts M. Barrande has produced? I do not think it. He has proved that there existed among the ancient cephalopods two great types, which have continued separate during the entire period of their existence; but the evolution of each of these types remains extremely probable, and conforms to observations made upon them. In such matters one cannot, in effect, ask more than a probability."*

* *Jour. de Zool.*, iv, 419, 1877.

<i>Western U. S.</i> Oregon beds. White River.	<i>Eastern U. S.</i> Yorktown Period.	Miocene.	Miocene.—Molasse (in part), Eningian, Tortonian? Sivalik? Lower Miocene.—Molasse (in part), Helvetian, Falunian, Bovey-Tracey.
Vicksburg (Orbitoid limestone).	Oligocene.	Oligocene. (Nummulitic in part.)	Upper O.—Aquitanean. Middle O.—Tongrian, Hempstead, Bembridge, Fontainebleau sandstone, Mayence Basin. Lower O.—Ligurian, Headon, Montmartre gypsum.
<i>Western U. S.</i> Uinta. Bridger. Green River. Wasatch.	<i>Eastern U. S.</i> Jacksonian. Claibornian. Buhrstone. (Siliceous Clayborne.) Eo-lignitic.	Eocene.	Upper E.—Parisian (Calcaire grossier), Bartonian, Lackenian, Bruxellian, Nummulitic (in part) Flysch? Middle E.—Londonian; Suesonian (in part), Ypresian. Lower E.—Oldhaven, Woolwich, Reading and Thanet series, Suesonian (in part), Argile plastique, Landenian. Heersian.

Tertiary.

AMERICAN.			EUROPEAN, ETC.	
<i>Beds, Synonyms.</i>	<i>Epochs.</i>	<i>Periods.</i>	<i>Epochs.</i>	<i>Beds, Synonyms.</i>
<i>Western U. S.</i> Laramie or Great Lignite. Fort Union. Judith River.	Laramie or Post-Cretaceous.	Laramie.		Maastrichtian (Danian), Faxö chalk, Calcaire pisolitique.
<i>Western U. S.</i> Fox Hills Group. Ripley. { Ft. Pierre. Rotten Colorado Group. Niobrara. Limestone. { Ft. Benton Dakota Group. Eutaw.	Cretaceous. (Green sand of New Jersey.)	Cretaceous.	Cretaceous. (Upper.)	{ Senonian (White Chalk). { Turonian (Chalk marl and chloritic marl), Hippuritic limestone.
			(Middle.)	{ Cenomanian (Upper Green- sand). { Gault.—Albian, Aptian, Ur- gonian. { Neocomian (Lower Green- sand), Upper Neocomian of d'Orbigny.
			(Lower.)	Wealden.—Weald Clay, Has- tings Sands, Panfield series, L. Neocomian of d'Orbigny.

<i>Western U. S.</i> Camarasaurus, Atlantosaurus and Sauranodon beds of Cope and Marsh.	Oolite.				Upper O.—Purbeckian, Portlandian, Kimmeridgian. Solenhofen states. Middle O.—Corallian. Oxfordian, Argovian. Callovian. Lower O.—Bathonian (Corn- brash, forest marble, Great Oolite). Bajocian (Fuller's earth, In- ferior Oolite). Upper L.—Toarcian. Middle L.—Liasian. Lower L.—Sinemurian.
		Jurassic.			Oolite. Lias.
Triassic deposits of the At- lantic border and those of the Western interior—both probably Jurassic in part (Connecticut red sandstone, etc.).		Triassic.		Rhætic. Keuper. Muschelkalk. Bunter-sand- stein.	Penarth beds, Dachstein. Saliferian, St. Cassian, Hallstadt. "Conchylien." Variegated sandstone, "Grès bigarré."

AMERICAN.		EUROPEAN, ETC.	
<i>Beds, Synonyms.</i>	<i>Epochs.</i>	<i>Periods.</i>	<i>Epochs.</i>
Strata of the interior Continental Basin—Texas.		Permian.	
			<i>Beds, Synonyms.</i> Magnesian limestone, Kupferschiefer. "Rothtodtliegende."
(Subcarboniferous.) Chester, St. Louis, Keokuk, Burlington & Kinderhook groups.	Coal Measures. Millstone grit. Mountain limestone.	Carboniferous.	Coal Measures. Millstone grit. Mountain limestone. (Subcarboniferous.)
Catskill.		Devonian (Old Red Sandstone).	
Chemung.	{ Chemung. Portage. Genesee.		Upper D.— Pilton group, Clymenian.
Hamilton.	{ Hamilton. Marcellus.		Middle D.— Ilfracombe group, Eifelian.
Corniferous.	{ Corniferous limestone (Upper Helderberg). Schoharie. Cauda-galli.		Lower D.— Lynton group, Spiriferian, Coblentzian.

Oriskany.	Upper Sil.—		Upper Sil.—	(3d fauna of Barrande—Étages E, F, G and H.) Ludovian. Wenlockian. May Hill. (2d fauna of Barrande—Étage D.) Llandoveryian. Caradocian (Bala). Llandeilian. Arenig.
Lower Helderberg. Salina (Onondaga). Niagara (Clinton and Medina).	Lower Sil.—	Silurian.	Lower Sil.—	
Cincinnati. { Hudson River. { Utica slates. Trenton. { Trenton limestone. { Black River “ { Bird’s eye “ { Chazy limestone. Quebec. { Quebec shales. { Calcareous.				
Potsdam sandstone. Acadian.	Cambrian.	Cambrian.	Upper C.— Lower C.—	(Primordial fauna of Barrande —Étage C. Tremadocian. Lingulian. Menevian. Harlech and Longmynd.
		Huronian.		

AMERICAN.		EUROPEAN, ETC.	
<i>Beds, Synonyms.</i>	<i>Epochs.</i>	<i>Periods.</i>	<i>Epochs.</i>
Norian, or U. Laurentian. Middle Laurentian. Bojan, or L. Laurentian.		Laurentian.	Fundamental gneiss, "Urgneiss," Bojangneiss, Hercynian gneiss.

Note.—The Laurentian and Huronian are collectively termed Archæan or Eozoic.
The Cambrian to Permian inclusive = Palæozoic (old "primary").
The Triassic to Cretaceous inclusive = Mesozoic (old "secondary").
The Laramie is classed by some as Mesozoic, by others as Kainozoic.
The Tertiary and Quaternary = Kainozoic or Neozoic.

For the above table of fossiliferous strata, prepared especially for this work, I am much indebted to Prof. Angelo Heilprin, who has been at considerable pains to correlate the American and European beds as nearly as possible, as well as to include all the names usually met with in geology and palæontology.

Fossil Mollusks of the Palæozoic Period.

"The study of the earliest manifestations of life upon the surface of the globe will always have great attraction for naturalists. In 1868, Bigsby prepared the following table of the primordial or Cambrian fauna, which includes 972 species.

Plantæ,	22	Asteridea,	1	Brachiopoda,	116
Amorphozoa,	27	Annelida,	29	Lamellibranchiata,	12
Cœlenterata,	6	Trilobita,	417	Pteropoda,	57
Crinoidea,	1	Entomostraca,	25	Gastropoda,	115
Cystidea,	2	Polyzoa,	77	Cephalopoda,	65

"Consequently, from the beginning the principal types of mollusca are represented; the gastropods are as well developed as the brachiopods, and the cephalopods surpass in number the pteropods, which are, nevertheless, inferior in organization. In the middle and upper beds of the Silurian, the brachiopods make an enormous increase; the cephalopods arrive at their apogee; then come, according to their importance, the gastropods, the lamellibranchs, and finally the heteropods and pteropods.

"In the Devonian and Carboniferous periods, the brachiopods sensibly diminish, and lose the first place, which is occupied by the lamellibranchs; the gastropods become more numerous than the cephalopods.

	Silurian.	Devonian.	Carbonif.	Total.
Brachiopods, species,	1650	695	875	3220
Lamellibranchs, species,	709	927	1214	2850
Gastropods, species,	895	621	674	2190
Pteropods and Heteropods, species,	338	138	108	604
Cephalopods, species,	1454	558	410	2424

"Consequently, in palæozoic periods the classes of Malacozoa occupy the following order according to the number of their species: 1, Brachiopods; 2, Lamellibranchiata; 3, Cephalopods; 4, Gastropods; 5, Pteropods and Heteropods.

"We can then characterize the palæozoic epoch as the age of brachiopods.

"We have no table of mollusks of the Permian, but it is scarcely probable that the fossils of this formation would modify the preceding conclusions.

"The Nautilidæ, among the cephalopods, shone with all their lustre during the Silurian; it is then that their genera presented the most varied forms. Orthoceras was multiplied to a degree unheard of, since in the single basin of Bohemia, Barrande has been able to distinguish 554 species.

"There lived in the Silurian seas at the same time some pelagic mollusks (pteropods and heteropods), belonging to the genera Bellerophon, Conularia, Maclurea. The gastropods were nearly all holostomate: Acroculia, Euomphalus, Loxonema, Murchisonia, Pleurotomaria, Platystoma. The principal lamellibranch-

chiates were Ambonychia, Pterinea, Avicula, Cardiola, Conocardium, Ctenodonta, Grammysia, Orthonota, Tellinomya, etc.

"The Devonian genera differ but little from those of the Silurian, but we must mention, among the cephalopods, Bactrites, Clymenia, Goniatites, Gyroceras; among the heteropods, Porcellia; among the gastropods, Scoliostoma, Loxonema, Turbo, Euomphalus, etc.; among the lamellibranchiates, Megalodon, Schizodus, Solenopsis, Aviculopecten, Stenopistha, etc.

"The Carboniferous is richer in species than the Devonian. The cephalopods are Goniatites, Nautilus of particular types, Orthoceras; the most common gastropods belonged to the genera Chiton, Euomphalus, Loxonema, Macrocheilus, Murchisonia, Pleurotomaria, Turbo; the pteropods and heteropods are generically similar to those of the Devonian; among the lamellibranchiates we cite the genera Aviculopecten, Allorisma, Solenomya, Astartella, Anthracosia, Cardiomorpha, Ctenodonta, Edmondia, Myalina, Schizodus, etc.

"The Permian fauna, very poor in mollusks, contains few generic types which are wanting to the Carboniferous. The important genera are: Nautilus, among the cephalopods; Chiton, Rissoa, Turbo, Natica, Macrocheilus, Pleurotomaria, Euomphalus, among the gastropods; Pecten, Lima, Monotis, Mytilus, Edmondia, Cardiomorpha, Bakewellia, Byssoarca, Pleurophorus, Schizodus, Astarte, Allorisma, Solemya, Eumicrotis, Myalina, among the lamellibranchs.

"Nevertheless this geological period presents to us a very important feature, the appearance of Ammonites properly so-called, represented by several species of Sageceras and Arcestes, which become important in the Trias. At the same time, the Goniatites became extinguished or transformed into Ammonites, which extend through the entire series of secondary rocks.

"A certain number of living genera have been indicated as palæozoic:

"Brachiopods.—Discina, Lingula, Rhynchonella, Terebratula.

"Lamellibranchs.—Avicula, Anomia, Pinna, Lima, Pecten, Ostrea, Plicatula, Amphidesma, Anatina, Anodonta, Arca, Astarte, Axinus, Cardium, Corbis, Crenella, Cucullæa, Donax, Dreissensia, Isocardia, Lithodomus, Lucina, Lutraria, Mactra, Lyonsia, Panopæa, Pandora, Pholadomya, Pullastra, Solemya, Solen, Yoldia, Teredo, Unio, Venerupis, Venus.

"Gastropods.—Aclis, Chiton, Eulima, Elenchus, Emarginula, Lacuna, Fusus, Helcion, Littorina, Natica, Narica, Paludina, Pyrula, Scalaria, Trochus, Turbo, Siphonaria, Tornatella, Turritella, Calyptræa, Capulus, Phasianella, Vermetus.

"Pteropods.—Cleodora.

"Cephalopods.—Nautilus, Spirula.

"But many palæontologists consider these identifications

erroneous, believing that the palæozoic forms, have only a superficial resemblance to living forms in their testaceous envelope. They can well suppose that animals essentially different were able to live in shells of the same form, since in our days we see analogous facts. For examples, may be cited the genera *Carelia*, *Glandina*, *Halia*, *Ferussacia*, which were considered as *Achatina*, until their anatomy became known.”*

Fossil Mollusks of Mesozoic time. “During the three principal formations of the mesozoic period (Triassic, Jurassic, Cretaceous), cephalopods of the family Ammonitidæ took an extraordinary development, and although the number of species was inferior to that of the lamellibranchs, or even of the gastropods, they nevertheless characterize the most of the stratified beds. Individually, they were as abundant relatively as were the brachiopods of palæozoic seas.

“The following table is prepared from the numbers furnished by Bronn in 1855.

	Triassic.	Jurassic.	Cretaceous	Total.
Brachiopods, species,	34	120	217	371
Lamellibranchs, “	245	1043	1590	2878
Gastropods, “	393	497	446	1336
Cephalopods, “	106	547	509	1162

“According to the number of their species the mesozoic Malacozoa may be thus classed: 1, Lamellibranchs; 2, Gastropods; 3, Cephalopods; 4, Brachiopods; 5, Pteropods and Heteropods—scarcely any. The mesozoic epoch may consequently be justly styled that of lamellibranchs. The predominance of this class of mollusks is nearly constant.

“If we follow in a determined geographical region, the regular succession of the beds, we will generally find the same relative proportions of the various mollusks. Thus the Liassic deposits of the basin of the Rhone, studied by Dumortier, give us these results:

*I do not think that Fischer could have selected more unfortunate examples in illustration of this argument. These genera are all readily distinguishable by the shell alone, and *Halia* was known to be a marine shell long before we knew anything of the animal. To adduce the errors of naturalists, which have arisen solely from carelessness in not noticing manifest characters as a proof that these characters cannot be depended on in fossil genera, when they are the *only* characters by which we shall ever be able to distinguish them is to change natural history from a science of observation to a speculative science. Fischer could scarcely have stated more plainly the developmentalist position, than he has done in the above paragraph, the meaning of which is: Since development is true, these ancient appearances of so many modern genera must be deceptive, however plausible. For myself, I prefer fact to theory, and until I can distinguish different generic characters in a palæozoic *Pholadomya*, I shall not doubt that it is a *Pholadomya*.

	Infra Lias	Lower Lias.	Middle Lias.	Upper Lias.	Total.
Brachiopods,	2	18	44	20	84
Lamellibranchs,	111	78	115	82	386
Gastropods,	74	36	78	66	254
Cephalopods,	9	63	65	111	248

“It is only in the Upper Lias that the cephalopods surpass the lamellibranchs.

“The type *Nautilus*, so rich and varied during palæozoic times, declines more and more through the Mesozoic beds. The last of the *Orthoceras* became finally extinguished in the Trias. In the Lias appeared *Belemnites*, which was perpetuated to the end of the Cretaceous period, and the abundance of which in those seas is as remarkable as that of *Orthoceras* in palæozoic seas. “The Trias is characterized by a great number of the subdivisions of *Ammonites*. Thus, we are acquainted, in this formation, with 130 species of *Arcestes*, and with numerous *Didymites*, *Lobites*, *Tropites*, *Clydonites*, *Ceratites*, *Trachyceras*, *Pinacoceras*, *Sageceras*. Among the uncoiled *Ammonites* may be cited *Cochloceras* and *Rhabdoceras*. The gastropods are very numerous; the limited fauna having been studied with care at Saint-Cassian; they are: *Chemnitzia*, *Loxonema*, *Rissoa*, *Eulima*, *Trochus*, *Turbo*, *Pleurotomaria*, *Cerithium*, *Helcion*, etc. The lamellibranchs belonged to the genera *Myophoria*, *Cardium*, *Leda*, *Nucula*, *Arca*, *Myoconcha*, *Mytilus*, *Avicula*, *Posidonomya*, *Pecten*, *Ostrea*, *Dicerocardium*, *Halobia*, etc.

“The Jurassic contains some peculiar types of *Ammonites*: *Arietites*, *Ægoceras*, *Harpoceras*, *Oppelia*, *Stephanoceras*, *Peltoceras*, etc.; some *Ammonites* with uncoiled whorls: *Toxoceras*, *Ancyloceras*; numerous species of *Belemnites*, and several other cephalopods approaching the *Calamaries*: *Palæoteuthis*, *Leptoteuthis*, *Acanthoteuthis*, etc. The characteristic gastropods belonged to the genera *Bourguetia* (*Phasianella*), *Pleurotomaria*, *Trochotoma*, *Pileolus*, *Rimula*, *Straparollus*, *Chemnitzia*, *Eucyclus*, *Nerinaea*, *Alaria*, *Spinigera*, *Purpuroidea*, *Cylindrites*, *Acteonina*. We cite among the lamellibranchs, the genera *Panopæa*, *Pholadomya*, *Astarte*, *Opis*, *Hippopodium*, *Ceromya*, *Cardinia*, *Trigonia*, *Unicardium*, *Lima*, *Pecten*, *Ostrea*, *Gryphæa*, *Gervillia*, *Pernostrea*, *Plicatula*, *Sowerbya*, *Cyprina*, *Isocardia*, *Pinnigera*, *Diceras*, *Hypotrema*, etc.

“In the Cretaceous appeared the sections of *Ammonites* for which have been proposed the genera *Sphenodiscus*, *Schloenbachia*, *Hoplites*, *Acanthoceras*, *Stoliczkaia*; *Ammonites* with uncoiled whorls became very numerous: *Crioceras*, *Ancyloceras*, *Baculites*, *Baculina*, *Ptychoceras*, *Hamulina*, *Scaphites*, *Toxoceras*, *Heteroceras*, *Helicoceras*, *Turrilites*. The exaggerated mutations of this type announce its near extinction. The *Belemnites* in the lower Cretaceous take forms not less unusual (*B. polygonalis*, *Emerici*, *dilatatus*); the genus *Belemnitella*

appears in the Cenomanian, and its existence is short. The cretaceous gastropods are relatively rare and belong to the genera *Scalaria*, *Turritella*, *Chemnitzia*, *Nerinaea*, *Avellana*, *Globiconcha*, *Varigera*, *Pterodonta*, *Natica*, *Trochus*, *Turbo*, *Pleurotomaria*, *Chenopus*, *Anchura*, *Voluta*, *Fusus*, *Mitra*, *Columbellina*, *Pleurotoma*, *Pyrula*; consequently the Siphonostomata commenced to develop.* The lamellibranchiates approached closely to living types; but several forms are lost; *Inoceramus*, *Myoconcha*, *Isoarca*, *Opis*, *Thetis*, and the entire series of the Rudistes (*Caprina*, *Caprinella*, *Caprotina*, *Radiolites*, *Hippurites*), which expired with the chalk, and the different horizons of which are so important to geologists.

Neozoic Fossil Mollusks. "Tertiary fossils nearly all belong to living types. The Ammonites, Belemnites, *Nerinaeas*, and Rudistes have become extinct.

"In 1855, Bronn knew more than 8000 species of tertiary mollusks, thus distributed:—

Brachiopods, . . .	52	Heteropods, Pteropods,	25
Lamellibranchs, . .	2445	Cephalopods, . . .	37
Gastropods, . . .	5310		

"The gastropods are dominant, then come the lamellibranchs. The cephalopods are completely in decadence and numerically inferior to the brachiopods. Consequently, the tertiary period was the period of gastropods, a domination which continues to the present time.

"In fact, if we compare the tertiary fauna of the Paris basin with the living fauna of the French coast we find the following confirmatory figures:—

	Basin of Paris (Deshayes).	Coast of France (Fischer).
Brachiopods, sp.,	15	8
Lamellibranchs, sp.,	1026	176
Gastropods, sp.,	1836	364
Cephalopods, sp.,	14	21

"The relative importance of the types of Malacozoa in the three great periods may be thus represented:—

	Palæozoic.	Mesozoic.	Neozoic.
Brachiopods,	1	4	3
Lamellibranchs,	2	1	2
Gastropods,	4	2	1
Cephalopods,	3	3	4

"Thus the brachiopods and cephalopods are to-day plainly in

* Dillwyn has observed that the shells of carnivorous gastropods were almost or entirely wanting in the palæozoic and secondary strata; but they were then replaced, in the economy of nature, by the now almost extinct order of tetrabranchiate cephalopods—of which several thousand species have been described.

decadence; the gastropods progressing, the lamellibranchs stationary.

“The peculiarly tertiary genera are pretty numerous. Among the cephalopods we cite: *Spirulirostra*, *Scaptorrhynchus*, *Beloptera*, *Belosepia*, *Vasseuria*, *Aturia*; among the gastropods: *Bifrontia*, *Borsonia*, *Cordieria*, *Volvaria*, *Deshayesia*, *Diastoma*, *Proto*, *Velainella*, *Pereiræa*, *Lesperonia*, *Velates*, etc.; among the lamellibranchs: *Teredina*, *Anisodonta*, *Psathura*, *Grateloupia*, *Lutetia*, *Pleurodesma*, *Pecchiola*, *Carolia*, *Tindaria*, etc.

“It is needless to add that the proportion of these lost genera diminishes as we ascend the series of stratified rocks, and that the number of modern types in the same degree increases.

“It is in accordance with this law, that Deshayes has been able to attempt a first classification of tertiary beds. He called Inferior Tertiary, those which contain but 2 per cent. of living species; Middle Tertiary, those which contain about 18 per cent. of them; and Superior or Upper Tertiary, those having a proportion of about 50 per cent. Lyell created the new names: eocene, miocene and pliocene for the divisions of Deshayes. More recently stratigraphy has permitted a rigorous establishment of their reciprocal relations, and the confirmation of the purely palæontological classification proposed by Deshayes.

Terrestrial and Fluvatile Fossil Mollusks. “The distribution in time of these mollusks is very interesting. They are wanting or extremely rare in the ancient beds and do not assume any importance before the tertiary period. According to Bronn, the principal changes in the exterior conditions of existence, consisted in the progressive development of the terrestrial surface, in the subdivision of the primordial universal ocean into the Mediterranean and Caspian Seas, in the elevation of plateaus and of mountain chains. A corresponding change was manifested in the organic world. With the first exclusively pelagic and swimming population, became associated a marine population, a littoral and finally a terrestrial one.

“The first terrestrial mollusks have been discovered in the Carboniferous and singularly resemble living forms. Authors have described a great number of Carboniferous terrestrial and fluvatile shells, but it appears that the supposed *Unios* are *Anthracosia*; the *Tichogonia*, *Avicula*; the (European) *Planorbis*, *Serpula*, etc. In America, however, we have undoubted terrestrial genera in the Carboniferous: *Pupa*, *Strophites* (allied to *Strophia*), *Zonites*, *Dawsonella*.

“In the continental (European) Jurassic formations are cited several *Cyrena*, *Neritina*, *Planorbis*, *Melania*, *Hydrobia*. The fauna of the superior lacustrine beds of the Jurassic (Purbeckian) and of the lower Cretaceous (Wealdian) is relatively rather rich. The principal genera are *Cyrena*, *Unio*, *Melania*, *Valvata*, *Hydrobia*, *Neritina*, *Planorbis*, *Physa*, *Limnæa*, *Auri-*

cula, Carychium. In the lower chalk of Europe many forms have been discovered which resemble living American types: Pleurocera, Lioplax, Goniobasis; in the middle and upper chalk, Cyrena, Melanopsis, Paludomus, Paludina, Melania, Glandina, Bulimus, Physa, Cyclotus, Cyclophorus (?), and Leptopoma (?) abound, mixed with extinct genera: Dejanira, Anastomopsis, Lychnus. The genera of the chalk period which still exist have in great part a quite different modern distribution.

"In the eocene of France, have been discovered Amphidromus, Glandina, Cyliodrella, Columna, Megaspira, Cyclophorus, Craspedopoma, associated with Melanopsis, Melania, Pirena, gigantic Physas, Cyrena, Unio, etc. The miocene and pliocene are characterized by numerous species of Helix, Pupa, Glandina, Cyclostoma, Megalomastoma, Strophostoma, colossal Clausiliæ, Testacella, Parmacella, Valenciennesia, Pyrgula, Fossarulus, Lithoglyphus, Paludina, Unio, Dreissensia, Dreissenomya, etc. The abundance of species and their variability was remarkable during the deposit of the Paludina-beds."

In America numerous land and fresh-water shells are found in the strata ranging from the Cretaceous to Eocene, which can not only be referred positively to existing genera, but even to smaller groups now existing; for instance, there are 5 groups of Helix, Planorbis 3 gr., Limnæa 3, Physa 2, Pupa 2, Succinea and Unio.

We cannot better conclude this short notice of fossil land and fresh-water shells, than by a reference to the remarkable tertiary deposits of Steinheim, which have caused much discussion among palæontologists.

At Steinheim, in Würtemberg, in what was once the bed of an ancient lake, pits have been dug, revealing a succession of tertiary strata of clay, shell-sand and limestone, and, commencing with several forms of one species of Planorbis, or with related species, it matters little which view is adopted, the superimposed strata show a gradual divergence from the primal types until in the latest deposits some of these have become so altered as to have more resemblance to turbinate Valvatæ than to Planorbis. That the extraordinary changes here produced were the result of extraordinary conditions, can scarcely be doubted, but it cannot be denied that here the gradual change wrought in specific characters has received an important practical demonstration. The latest forms are *proved* to have been evolved from the earliest, for the whole history of the evolution is laid bare in the series of strata through which the innumerable specimens of these Planorbes are disseminated. It is believed that, in this case, the deposition of the strata was rather rapid, and therefore no great amount of time was required to make the transitions of form.*

* The Genesis of the Tertiary Species of Planorbis at Steinheim (Würtemberg). By Alpheus Hyatt. Anniversary Memoirs of the Boston Soc. of Nat. History, 1880.

Extension of Species, Genera and Families.—"The distribution of species in the fossiliferous beds is comparable to that of living species in space. In fact, we find a bed where each species has its maximum of numbers; above and below this bed, it is only represented by less numerous individuals, or has disappeared. If the locality where the first individuals of the species appeared is very distant from that in which the last of them occur, one can thus appreciate their geographical migrations during the interval.

"The study of the distribution of fossil genera, compared to that of the same genera living, will give interesting results and reveal considerable modifications in the condition of ancient seas and continents.

"We are led to believe that each genus has had a centre of creation or of diffusion;* or that (according to the development theory), each genus has become constituted within a determined region. The enormous geographical extension of several fossil genera, has supported the supposition that there existed many centres of creation, but the diffusion of embryonic marine Malacozoa is so easy, that it appears useless to have recourse to this hypothesis.

"All the genera of mollusks are not equally plastic, nor modified by time. Nautilus, Natica, Arca, Nucula, Chiton, Lingula, Terebratula, Rhynchonella, etc., have had a much greater longevity than the others, and more or less resemble living forms. Terrestrial and fluviatile mollusks are relatively less changed than marine mollusks; Melanopsis, Planorbis, Pupa of the ancient beds, scarcely differ at all from living forms.

"This resistance of certain mollusks to modification, contrasts with the extreme plasticity of types of echinoderms, reptiles and mammals, by which the thinnest stratigraphical horizons can be characterized.

"The cause of the persistence of these types is unknown. To say that with them the law of heredity is stronger than the law of variability, is not an explanation. Then again, many genera of mollusks, after enduring through several geological periods, suddenly become extinct. Others have made but an appearance, so to say, upon the surface of the globe. These

* L. Agassiz and Prof. E. Forbes have represented diagrammatically, the distribution of genera in time, as well as their duration, by means of a horizontal line crossing perpendicular columns representing the formations; its left extremity touches where the genus first occurs, its right extremity where it became extinct; the line is swelled or thickened according to the amount of development of the species in the various strata. For example, a line thus  indicates that the genus has become extinct, and that it became most largely developed at the middle period of its duration; a line  indicates that the genus has been developing to the present moment, which is, so far, its maximum.

last are the most precious for geologists, because they become characteristic."

TABLE OF CHARACTERISTIC GENERA.

SYSTEMS.	GENERA AND SUB-GENERA.
1. CAMBRIAN, or Lower Silurian...	{ Cameroceras, Endoceras, Gonioceras, Pterotheca. Maclurea, Raphistoma, Holopea, Platyceras. Orthisina, Platystrophia, Porambonites, Pseudo-crania. Ambonychia, Modiolopsis, Lyrodesma.
2. SILURIAN.....	{ Actinoceras, Phragmoceras, Trochoceras, Ascoceras. Theca, Holopella, Murchisonia, Atrypa, Retzia. Cardiola, Clidophorus, Goniophorus, Grammysia.
3. DEVONIAN.....	{ Bactrites, Gyroceras, Clymenia, Apioceras, Serpularia. Spirifera, Uncites, Merista, Davidsonia, Calceola. Stringocephalus, Megalodon, Orthonota, Pterinea.
4. CARBONIFEROUS...	{ Nautiloceras, Discites, Goniatites, Porcellia. Naticopsis, Platychisma, Metoptoma, Productus. Aviculo-pecten, Anthracosia, Conocardium, Sedgwickia.
5. PERMIAN.....	{ Camarophoria, Aulosteges, Strophalosia. Myalina, Bakewellia, Axinus, Edmondia.
6. TRIAS.....	{ Ceratites, Naticella, Platystoma, Koninckia, Cyrtia. Monotis, Myophoria, Pleurophorus, Opis.
7. L. JURASSIC.....	{ Belemnites, Beloteuthis, Geoteuthis, Ammonites. Alaria, Trochotoma, Rimula, Pileolus, Cylandrites. Waldheimia, <i>Thecidium</i> , Spiriferina, Ceromya. Gryphæa, Hippopodium, Cardinia, Myoconcha.
8. U. JURASSIC.....	{ Coccoteuthis, Leptoteuthis, Nautilus. Spinigera, Purpurina, Nerinæa, Neritoma. Pteroperna, Trichites, Hypotrema, Diceras.
9. L. CRETACEOUS....	{ Trigonina, Pachyrisma, Sowerbia, Tancredia. Crioceras, Toxoceras, Hamulina, Baculina. Requienia, Caprinella, Sphæra, Thetis.
10. U. CRETACEOUS...	{ Belemnitella, Conoteuthis, Turrilites, Ptychoceras. Hamites, Scaphites, Pterodonta, Cinulia, Tylostoma. Acteonella, Globiconcha, Trigonosemus, Magas, Lyra. Neitheia, Inoceramus, Hippurites, Caprina, Caprotina.
11. EOCENE.....	{ Beloptera, Lychnus, <i>Megaspira</i> , <i>Glandina</i> , <i>Typhis</i> . <i>Volutilithes</i> , <i>Clavella</i> , <i>Pseudoliva</i> , <i>Seraphs</i> , <i>Rimella</i> . Conorbis, Strepsidura, Globulus, <i>Phorus</i> , Velates.
12. MIOCENE.....	{ Chilostoma, Volvaria, Lithocardium, Teredina. Spirulirostra, Aturia, Vaginella, Ferussina. Halia, Proto, Deshayesia, <i>Niso</i> , <i>Cassidaria</i> , Carolia.
13. PLIOCENE.....	{ Grateloupia, <i>Artemis</i> , <i>Tapes</i> , <i>Jouannetia</i> . <i>Argonauta</i> , <i>Strombus</i> , <i>Purpura</i> , <i>Trophon</i> . <i>Yoldia</i> , <i>Tridacna</i> , <i>Circe</i> , <i>Verticordia</i> .

In the above table will be found the list of 13 geological systems, each having a certain number of special genera. Some of the genera cited, for example, Belemnites, have a greater extension, but are mentioned by reason of their abundance in a particular system. Names in italics are those of living genera.

The following table contains some of the larger genera arranged in the order of their appearance.

RANGE OF GENERA IN TIME.

[illegible]

“ The same method of tabulation applied to families, that is, to groups formed of related genera, shows that the extinct families are relatively few in number. Among the reptiles, on the contrary, a large number of families and even several orders no longer exist (Dicynodonts, Labyrinthodonts, Enalliosaurians, Dinosaurians, etc.). The invertebrata, consequently, have varied less than the vertebrata.

“ Woodward, who has prepared the following table, indicates only seven extinct families: Belemnitidæ, Ammonitidæ, Orthoceratidæ, Spiriferidæ, Orthisidæ, Productidæ, Hippuritidæ. It is evident that this list might be lengthened, but it can be said in general that the important fossil types of mollusks which no longer exist are relatively few in number.

RANGE OF FAMILIES IN TIME.

Systems of Strata. }	Cambrian.	Silurian.	Devonian.	Carbonif.	Permian.	Trias.	L. Jura.	U. Jura.	L. Cret.	U. Cret.	Eocene.	Miocene.	Pliocene.	Recent.
Argonautidæ,													-	-
Teuthidæ—Sepiadæ,							-	-	-	-	-	-	-	-
Belemnitidæ,							-	-	-	-				
Nautilidæ,		-	-	-	-	-	-	-	-	-	-	-	-	-
Ammonitidæ,			-	-	-	-	-	-	-	-				
Orthoceratidæ,	-	-	-	-	-	-								
Atlantidæ—Hyaleidæ,	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Strombidæ—Buccinidæ,										-	-	-	-	-
Conidæ—Volutidæ,										-	-	-	-	-
Naticidæ—Calyptræidæ,			-	-	-	-	-	-	-	-	-	-	-	-
Pyramidellidæ,	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cerithiadæ—Littorinidæ,						-	-	-	-	-	-	-	-	-
Turbinidæ—Ianthinidæ,	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fissurellidæ—Tornatellidæ,				-	-	-	-	-	-	-	-	-	-	-
Neritidæ—Patellidæ,							-	-	-	-	-	-	-	-
Dentaliadæ,			-	-	-	-	-	-	-	-	-	-	-	-
Chitonidæ,	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bullidæ,							-	-	-	-	-	-	-	-
Helicidæ—Limacidæ,											-	-	-	-
Limnæidæ—Melaniadæ,								-	-	-	-	-	-	-
Auriculidæ—Cyclostomidæ,										-	-	-	-	-
Terebratulidæ,			-	-	-	-	-	-	-	-	-	-	-	-
Rhynchonellidæ,	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Spiriferidæ—Orthisidæ,	-	-	-	-	-	-	-							
Productidæ,	-	-	-	-	-									
Craniadæ—Lingulidæ,	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Systems } of Strata. }	Cambrian.	Silurian.	Devonian.	Carbonif.	Permian.	Trias.	L. Jura.	U. Jura.	L. Cret.	U. Cret.	Eocene.	Miocene.	Pliocene.	Recent.
Pectinidæ,				—	—	—	—	—	—	—	—	—	—	—
Aviculidæ—Mytilidæ,	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Arcadæ—Trigoniadæ,	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Unionidæ,									—	—	—	—	—	—
Chamidæ—Myadæ,								—	—	—	—	—	—	—
Hippuritidæ,									—	—				
Tridacnidæ,													—	—
Cardiadæ—Lucinidæ,		—	—	—	—	—	—	—	—	—	—	—	—	—
Cycladidæ,								—	—	—	—	—	—	—
Cyprinidæ—Anatinidæ,	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Astartidæ,						—	—	—	—	—	—	—	—	—
Veneridæ—Tellinidæ,								—	—	—	—	—	—	—
Mactridæ,										—	—	—	—	—
Solenidæ,				—	—	—	—	—	—	—	—	—	—	—
Gastrochænidæ—Pholadidæ,							—	—	—	—	—	—	—	—

Three families are nearly extinct :—
Nautilidæ. Rhynchonellidæ. Trigoniadæ.
And several have passed their maximum, and become less varied and abundant than formerly, *e. g.*—

Tornatellidæ. Cyprinidæ. Anatinidæ.
The extinct families and genera appear to have attained their *maxima* more rapidly than their *minima*; continuing to exist, under obscure forms, and in remote localities, long after the period in which they flourished.

The introduction of new forms, also, is more rapid than the process of extinction. If four Palæozoic families disappear, twenty-six others replace them in the Secondary series; and three of the latter are succeeded by fifteen shell-bearing families in the Tertiary and existing seas.

In consequence of this circumstance, the number of types is three times greater in the newer Tertiary than it was at the Silurian period; and since there is no evidence or indication that the earth was ever destitute of life, either wholly or in part, it follows almost as a matter of necessity that the early types must have been more widely distributed and individually developed, than those of the present day.

From the following table it will be seen that the number of genera and families increases with an amount of regularity which cannot be accidental. Moreover, the relation of these numbers is not liable to be much altered by the progress of dis-

covery or the caprice of opinion. The *discovery* of new types is not likely to be frequent; the imposition of new names, in place of the old, will not increase the number of Palæozoic genera; and the establishment of fresh and arbitrary distinctions will affect all the groups in due proportion.

If the number of groups called "Systems" were reduced to seven (viz., three Palæozoic, three Secondary, and one Tertiary, as shown in the following table), then the *average* duration of a genus of shells would be equal to a System of Formations.

The duration of the smallest well-defined Families of shells is about equal to one of the three great geological divisions, or ages.—WOODWARD.

DEVELOPMENT OF FAMILIES, GENERA, AND SPECIES, IN TIME.

GEOLOGICAL SYSTEMS.		Total of Genera.	Cephalopoda.	Gastropoda.	Brachiopoda.	Conchifera.	Total Number of Species (l'Orbigny).	Families.
PALÆOZOIC.	1 { Cambrian	49	12	11	15	11	362	18
	2 { Silurian	53	13	11	16	13	317	20
	3 { Devonian	77	14	20	23	20	1035	24
	4 { Carboniferous . .	79	11	26	19	23	835	30
	5 { Permian	66	6	24	16	20	74	30
SECONDARY.	6 Trias	81	9	25	16	31	713	35
	7 { L. Jurassic	107	12	35	12	48	1502	42
	8 { U. Jurassic	108	13	36	9	50	1266	49
	9 { L. Cretaceous . .	123	20	41	9	53	784	52
	10 { U. Cretaceous . .	148	16	59	14	59	2147	56
TERTIARY.	11 { Eocene	172	4	85	11	72	2636	60
	12 { Miocene	178	3	97	11	76	2242	60
	13 { Pliocene	192	1	100	12	79	437	62
	14 Recent	400	21	251	13	115	16,000	78
Recent and Fossil.		520	56	280	34	150	30,000	85

A few words as to certain relations of fossil faunas with those now existing, will close this portion of our work.

Phillips has said that the Jurassic period has its parallel in the existing fauna of Australia. The Jurassic mammals are, in fact, Didelphians; and among Jurassic marine mollusks, Trigonina still exists in Australian seas.

“Forbes found the chalk deposits similar to those at the bottom of the Ægean Sea. Recently, Wyville Thompson has developed this hypothesis, after the study of the bottom of the Atlantic, and he believes the cretaceous period to have continued to the present time in the abyssal zone; where are living genera of echinoderms, sponges and crustaceans, similar to those of the white chalk. Unfortunately the conchological fauna only furnishes negative arguments; the relations of these mollusks being only with those of the pliocene and post-pliocene beds.

“The eocene fossils of the basin of Paris belong to genera now confined to tropical seas: Rostellaria, Oliva, Ancillaria, Voluta, Mitra, Pyrula, Xenophora, Typhis, Pseudoliva, Fusus, Vulsella, Crassatella, Cardilia, Corbis, Pholadomya, Perna, Nautilus, etc. The terrestrial genera of this basin: Cyclophorus, Cyclotus, Megaspira, Cyliodrella, are now distributed through the inter-tropical regions of America. The eocene fauna of Europe thus has a more tropical character than its living fauna.

“The miocene genera of the basins of Bordeaux, Touraine, and Vienna are to-day distributed in the Indian Ocean, West Coast of Africa and Antilles: Ancillaria, Oliva, Eburna, Terebra, Cyllene, Strombus, Rostellaria, Ficula, Melongena, Fasciolaria, Turbinella, Sigaretus, Tugonia, Perna, Ungulina, etc.

“During the pliocene the *Astrea* polyps disappeared from the Mediterranean, the waters became colder, the great *Pleurotomas* became extinct, and the fauna took the characters of that which is now existing. A considerable cooling permitted the glacial species which existed in the Crag to penetrate to the Mediterranean.

“Finally, the quaternary period is that, for which great oscillations of the earth, cataclysms, displacements of currents, are invoked to explain certain geological and palæontological facts. The axis of rotation of the earth itself has been displaced by certain theorists. The explanation of these hypotheses would take us too long. Suffice it to say that in our quaternary beds are found Alpine terrestrial shells mixed with those now living upon the plains, and with exotic types (*Corbicula*); just as they contain mammoths, reindeer, hippopotami and lions—an assemblage which now appears to us paradoxical. This last period, so close to us is thus the most obscure. It renders palpable the inanity of our science in presence of the great geological and palæontological problems which still remain unsolved. What, then, is it which has chiefly determined the character of the present zoological provinces? What law, more powerful than climate, more influential than soil, and food, and shelter; nay, often seemingly producing results opposed to *à priori* probability, and at variance with the suitableness of conditions?

"The answer is, that each fauna bears, above all things, the impress of the age to which it belongs. Each has undergone a series of vicissitudes up to the time when its barriers became fixed, and after its isolation it has known no further change, but decline."

The number of living and fossil species of each genus of mollusca will be stated in the following pages, so far as they can be ascertained. The following table of the relative numerical development of the orders and families, is taken from Woodward and shows the extent of conchological knowledge twenty-five years ago:—

	Recent.	Fossil.		Recent.	Fossil.
CEPHALOPODA. <i>Dibranchiata.</i>			Patellidæ, . . .	368	104
Argonautidæ, . . .	4	2	Dentaliadæ, . . .	50	125
Octopodidæ, . . .	63	—	Chitonidæ, . . .	250	37
Teuthidæ, . . .	104	31		—	—
Belemnitidæ, . . .	—	140		8465	5819
Sepiadæ, . . .	30	16	<i>Pulmonifera.</i>		
Spirulidæ, . . .	3	—	Helicidæ, . . .	4750	316
	—	—	Limacidæ, . . .	93	4
	204	189	Limnæidæ, . . .	332	185
<i>Tetrabranchiata.</i>			(Marine), . . .	193	37
Nautilidæ, . . .	6	593	(Ditto, shell-less),	36	—
Orthoceratidæ, . . .	—			—	—
Ammonitidæ, . . .	—	1600		5404	542
	—	—	<i>Operculated Pulmonifera.</i>		
	6	2193	Cyclostomidæ, . . .	903	45
GASTROPODA. <i>Prosobranchiata.</i>			Aciculidæ, . . .	28	1
Strombidæ, . . .	87	393		—	—
Muricidæ, . . .	993	703		931	46
Buccinidæ, . . .	1144	352	<i>Tectibranchiata.</i>		
Conidæ, . . .	856	462	Tornatellidæ, . . .	62	166
Volutidæ, . . .	686	210	Bullidæ, . . .	168	88
Cypræidæ, . . .	227	97	Aplysiadæ, . . .	84	4
Naticidæ, . . .	268	340	Pleurobranchidæ,	28	5
Pyramidellidæ, . . .	216	394	Phyllidiadæ, . . .	14	—
Cerithiadæ, . . .	192	610		—	—
Melaniadæ, . . .	424	50		356	263
Turritellidæ, . . .	329	290	<i>Nudibranchiata.</i>		
Littorinidæ, . . .	410	220	Doridæ, . . .	160	—
Paludinidæ, . . .	217	110	Tritoniadæ, . . .	38	—
Calyptræidæ, . . .	160	101	Æolidæ, . . .	101	—
Turbinidæ, . . .	855	906	Phyllirhoidæ, . . .	6	—
Haliotidæ, . . .	104	136	Elysiadæ, . . .	13	—
Fissurellidæ, . . .	201	76		—	—
Neritidæ, . . .	428	103		318	

	Recent.	Fossil.		Recent.	Fossil.
<i>Nucleobranchiata.</i>			CONCHIFERA.		
Firolidæ, . . .	33	1	Ostreidæ, . . .	426	1362
Atlantidæ, . . .	22	159	Aviculidæ, . . .	94	638
	—	—	Mytilidæ, . . .	217	331
	55	160	Arcadæ, . . .	360	1142
PTEROPODA.			Trigoniadæ, . . .	3	139
Hyaleidæ, . . .	52	95	Unionidæ, . . .	549	58
Limacinidæ, . . .	19	—	Chamidæ, . . .	50	62
Clionidæ, . . .	14	—	Hippuritidæ, . . .	—	103
	—	—	Tridacnidæ, . . .	8	3
	85	95	Cardiadæ, . . .	200	360
BRACHIOPODA.			Lucinidæ, . . .	178	446
Terebratulidæ, . . .	67	340	Cycladidæ, . . .	176	144
Spiriferidæ, . . .	—	380	Cyprinidæ, . . .	176	956
Rhynchonellidæ, . . .	4	422	Veneridæ, . . .	600	329
Orthidæ, . . .	—	328	Mactridæ, . . .	147	58
Productidæ, . . .	—	146	Tellinidæ, . . .	560	388
Craniadæ, . . .	5	37	Solenidæ, . . .	63	81
Discinidæ, . . .	10	90	Myacidæ, . . .	121	334
Lingulidæ, . . .	16	99	Anatinidæ, . . .	246	400
	—	—	Gastrochænidæ, . . .	40	35
	102	1842	Pholadidæ, . . .	81	50
				—	—
				4295	7419

GENERAL SUMMARY.

	Recent.	Fossil.		Recent.	Fossil.
Dibranchiata, . . .	204	189	Nudibranchiata, . . .	318	—
Tetrabranchiata, . . .	6	2193	Nucleobranchiata, . . .	55	160
Prosobranchiata, . . .	8465	5819	Pteropoda, . . .	85	95
Inoperculated Pul-			Brachiopoda, . . .	102	1842
monifera, . . .	5404	542	Conchifera, . . .	4295	7419
Operculated Pul-				—	—
monifera, . . .	931	46		20,502	18,568
Tectibranchiata, . . .	356	263			

NOMENCLATURE.

It is a reproach to natural science, and to no department thereof more than to conchology, that most of its votaries consider the determination of species and genera its legitimate end; that is, that they are more actuated by the selfish ambition of acquiring reputation than by the love of knowledge. As the builder finds it convenient to express the kinds of instruments used in his labor, by technical names, so do naturalists find necessary a succinct designation of the subjects of their studies; and the naming and technical description of species, in the same manner distinguishes for us the implements which we should use in our investigation of nature—implements by which the Great Builder has worked, in which He has expressed His thought. The proper acquisition of a language requires the preliminary knowledge of its grammar, the knowledge of letters precedes reading: even so, the simple name of a species, then of a genus, and its recognition when met with or referred to, forms the mere alphabet of science, from which we proceed gradually to the consideration of individual properties, then to intimate and to wider relationships, until we are fortified with sufficient knowledge to generalize. In these latter days generalizations are numerous enough, but unfortunately they are usually the product of minds not furnished with the requisite intimate knowledge of the factors upon which they build their generalizations.

Prior to the works of Linnæus binomial nomenclature was employed in natural history descriptions by several authors, and notably by Tournefort in botany; yet Linnæus was the first to use it throughout the animal and vegetable kingdoms, and he has accordingly been considered the founder of a system which he only extended and perfected. His principal rules still form the foundation of modern nomenclature. They are, as at present generally accepted, these: Every name applied to a natural object should consist of a generic followed by a specific name, each consisting of a single word. These names should be of Latin or Greek derivation, or Latinized if otherwise derived. The generic name is always with a capital initial letter, the specific name with a small initial, with the exception of personal, including mythological names, and of those which denote localities. With regard to these exceptions the practice is far from uniform; some strict Latinists writing all specific names with a small initial, whilst the most of authors give the capital initial to personal, and a respectable minority of them to geographical names. The former receive a genitive, the latter an adjective form.

Originally names were supposed to express qualities of the

objects to which they were applied, but the vast multiplication of descriptions of natural objects has caused some doubt as to the propriety of using such names, especially for species: thus, *Paludina viridis*, meaning the green paludina, a good-enough designation at one time, becomes confusing when fifty other equally green species of the same genus have become known to us, and so on, of other qualities, and especially of those designated comparatively—as small, smallest, largest, etc. A specific name which expresses no quality of the species and thus only becomes associated with the latter arbitrarily is decidedly favored by many modern students. Genera are usually printed in caps, species in small caps, synonyms (of which more hereafter) in italics; but when these names occur in the body of a text they are indifferently printed in italics.

All names, generic or specific, are followed by the full or contracted name of the author thereof. Apart from the personal considerations causing the adoption of this practice, there are others of purely scientific importance. The principal of these is, that owing to the insufficiency of a description or the stupidity of those who fail to understand a sufficient diagnosis, the name originally applied by one author to some object, comes to be applied by another and subsequent author to another object, usually more or less related to the first; or an original description may prove to cover two or more distinct species, and then one of these must be selected by a subsequent author to retain the original name, whilst the others receive new ones. In such, and other similar cases, the addition of the author's name informs us that the species referred to is, for instance, that named by Linnæus, and *not* the different object similarly named in error by Lamarck.

The love of scientific reputation, haste, the want of the painstaking and discriminating qualities which should distinguish a naturalist, above all the practice of working in localities where reference to the many thousands of publications on natural history is inconvenient or impossible, have led to a deplorable duplication of generic and (principally) specific names and diagnoses. It has been universally agreed to prefer in all such cases the name first published with a sufficient diagnosis, the other or subsequently printed names becoming synonyms. It is also generally agreed by conchologists to accept no specific names dated earlier than 1758, when Linnæus published the 10th edition of his *Systema Naturæ*. The exceptions are mainly generic names, some of the great Swede's predecessors far surpassing him in their appreciation of generic characters. For many of the older and generally less accurately described objects the synonymy has become prodigious, and even at the present day, some of the reasons given above are so active in the pro-

duction of synonyms that these form an immense annual crop, the extirpation of which occupies most of the time of those engaged in systematic work.

I give examples of the synonymy of four common European species from Fischer:—

SCROBICULARIA PIPERATA, Gmelin, sp.	SAXICAVA ARCTICA, Linné, sp.
Calicinelle, Adanson.	Mya arctica, Linné.
Macra piperata, Gmelin.	Solen minutus, Linné.
Macra Listeri, Gmelin.	Donax rhomboidea, Poli.
Venus gibbula, Gmelin.	Donax iris, Olivi.
Trigonella plana, Da Costa.	Didonta bicarinata, Schumacher.
Mya Hispanica, Chemnitz.	Biapholus spinosus, Leach.
Venus borealis, Pennant.	Pholobia præcisa, Brown.
Mya Gaditana, Gmelin.	Rhomboides rugosus, Blainville.
Scrobicula arenaria, Schumacher.	Hiatella monoperta, Bosc.
Macra compressa, Pulteney.	Mya elongata, Brocchi.

AKERA BULLATA, Müller.	NASSA COSTULATA, Renieri, sp.
Bulla akera, Gmelin.	Buccinum costulatum, Renieri.
Bulla soluta, Salis.	Buccinum Cuvieri, Payraudeau.
Bulla Norwegica, Bruguière.	Buccinum Ferussaci, Payraudeau.
Bulla resiliens, Donovan.	Planaxis lineolata, Risso.
Bulla fragilis, Lamarck.	Planaxis riparia, Risso.
Akera flexilis, Brown.	Buccinum flexuosum, Costa.
Akera Hanleyi, Adams.	Buccinum elegans, Costa.
Eucampe Donovanii, Leach.	Buccinum variabile, Philippi.
Bulla elastica, Sandri.	Buccinum tessellatum, Scacchi.
	Buccinum unifasciatum, Kiener.

“The multiplication of synonyms having made it desirable (as we have shown) to place the *authority* after each name, another source of evil has arisen; for several naturalists (fancying that the *genus-maker*, and not the *species-maker*, should enjoy this privilege) have altered or divided almost every genus, and placed their signatures as authorities for names given half a century or a century before by Linnæus or Bruguière. The majority of naturalists have disowned this practice, and agreed to distinguish by the addition of ‘sp.’ the authorities for those specific names of which the generic appellations have been altered. The *type* of a genus should be the species which best exhibits the characters of the group, but it is not always easy to follow out this rule: and consequently the first on the list is often put forward as the type.”—WOODWARD.

Latin was formerly the universal language of learning, and so became for a long period the only recognized language of science; in many cases descriptions not written in Latin were entirely ignored, Habit, and the authority of several scientific bodies

still cause it to be employed in most cases for a short characteristic description; but the numerous minor points—especially comparative characters now constituting the really essential portions of the description, are usually given in the vernacular of the author. Latin is not well adapted to the refinements of modern species-making and its final disuse is probably not far distant. Meantime the student is subjected to much inconvenience, unless his preparation embraces a useful knowledge of at least the Latin, English, German, French and Italian languages.

The Latin diagnosis, as now written, is usually worthless for the purpose of identification. It is simply a ceremonial through which the author becomes invested with the title to a specific name; it does not and cannot, and is not ordinarily intended to define his property with sufficient accuracy to prevent trespass on his rights by others; therefore it becomes a trap for the unwary and ambitious. On the other hand, the indefiniteness of the usual diagnosis permits its author the greatest latitude in shifting its object from species to species; or, if he is enterprising, in capturing some of the species diagnosed at a later date by his brother conchologists.

It remains to define the meaning of the words species, variety, genus, family, etc.

All the specimens or individuals, which are so much alike that we may reasonably believe them to have descended from a common stock, constitute a species. A species, therefore, must be capable of reproducing its like, subject to no other variations than those occasioned by the slow operation of changes of environment, food, etc. For the old idea of the immutability of species, each specially created in its present form, must be substituted that of practical immutability at a given period. Whilst some species have preserved their characters intact since the tertiary epoch, others show a gradual evolution of characters, distinguishing them from their common progenitor. Forms differing from specific types in an inferior degree may fall within the range of individual variation, and their characters, individual only, return to the parent stock; or, the combined operation of the laws of heredity, of selection, of environment may perpetuate in their descendants the differential characters and so, according to the degree of development of these characters we have varieties or new species. In fact varieties, conchologically understood; that is, possessing transmissible characters of sufficient importance to require naming and description are incipient species. Form, coloration and sculpture furnish the principal characters of species, whilst genera are collections of species possessing some more important character in common, whether derived from the animal or shell. Subgenera possess the essential generic character and in addition some character of

inferior importance peculiar to the subgeneric group. Subgenera may thus be regarded as incipient genera. Families are groups of allied genera possessing in common some character (generally structural); and subfamilies are distinguished by somewhat inferior but peculiar characteristics from the families. Families usually receive the name of the principal genus with the termination *idæ*. Thus the genus *Helix* belongs to the family *Helicidæ*. Subfamilies take the termination *inæ* with the name of the principal genus: thus we have the family *Muricidæ*, with the subfamilies *Muricinæ* and *Purpurinæ* for the groups of genera typified by *Murex* and *Purpura*. Suborders, orders, subclasses and classes are assemblages similarly constituted; only in each step made, the characters pervade a larger group of species, etc., and thus become more and more important in the structure and economy of the animal.

In an ideal classification each group of similar systematic value would possess structural characters of equal importance. If such military order and subordination existed in nature, it might readily be perverted by our want of perception and judgment; but many naturalists have become satisfied that the same laws which have produced variation in the individual, work to produce variation in every characteristic, be it of minor or major importance, and therefore the sharp lines of demarkation, indicated by the systematic scheme do not exist in nature, they are fictions necessary in classification, for the purpose of indicating certain agreed-upon stages of a continuous chain of differentiation. Sufficient evidence has accumulated from the study of palæontology, embryology and comparative anatomy to fully sustain this evolutionary idea of nature, as to most of the inferior systematic divisions, but the evidence is still insufficient to show conclusively the evolution of orders and classes within the subkingdom *Mollusca*, or of that subkingdom with the others from some common ancestral type. The classes and principal orders of the mollusca exhibit their structural characteristics (so far as these can be indicated by the shell and other preserved portions of the animal) from their first geological appearance. It may be added that certain genera have maintained these original characters from the older fossiliferous deposits to the present time.

"Great difficulty has always been found in placing groups according to their affinities. This cannot be effected in—the way in which we are compelled to describe them—a single series; for each group is related to *all* the rest; and if we extend the representation of the affinities to very small groups, any arrangement on a plane surface would fail, for the affinities radiate in all directions, and the 'network' to which Fabricius likened them, is as insufficient a comparison as the 'chain' of older writers."—WOODWARD.

CLASSIFICATION.

A detailed history of the progress of the science of conchology from the most ancient period to the present time, would be both interesting and instructive: want of space prevents the insertion of such an account here.

The following rapid sketch of the history of the modern classification of mollusks and exposition of a system, based principally on the lingual armature of the gastropods, is translated and condensed from a paper by the late Prof. Mörch, published in the *Journal de Conchyliologie* (xv, 232, 1867).

Ancient authors classified shells according to external forms, from which they derived generic names. Linnæus was the first to introduce characters independent of the form of the shell; as the teeth and ligament in bivalves, plications and sulcations in univalves. By these characters *Voluta* and *Turbinella* were separated from *Murex*, *Buccinum*, etc.

Linnæus classed the species of each genus, according to the height of the spire, in analogous sections, of which the most were adopted by Bruguière as distinct genera. Thus the following genera were terminated by a section "turrita," *Bulla* by *Achatina*; *Buccinum* by *Terebra*; *Strombus* by *Potamides* and *Pirena*; *Murex* by the spiny *Cerithiæ*; *Trochus* by *Telescopium* and *Pyramidella*; *Turbo* by *Turritella*; *Helix* by *Melania* and *Limnæa*.

Linnæus was the first to take the form of the animal into consideration as a generic character; but he indicated only five different types of animals, namely; *Doris*, *Limax*, *Tethys*, *Sepia*, and *Ascidia*. Thus the animal of *Chiton* is a *Doris*, that of *Argonauta* a *Sepia*; bivalves with simple mantle are *Ascidia* (*Solen*, *Mya*, *Pholas*), and those with fringed mantle *Tethys*. Nearly all the univalves are called *Limax*.

Adanson must be regarded as the founder of Malacology, but the number of mollusca known in his time was too few to permit the elimination of the principal systematic divisions. He was also the first to take into consideration the operculum and the shell structure as characters, and to divide the bivalves according to the number of muscular impressions.

The system of Cuvier, based on the respiratory organs, induced a great reform in Conchology. The shells of pulmonate mollusks, heretofore dispersed by all authors, with the exception of Adanson, among the pectinibranchs, were assembled in one group, which still remains intact. Although it may be difficult to indicate by a description the difference which exists between the shell of a pulmonate and that of a branchiate mollusk, there are, nevertheless, few collectors who will not recognize it at

sight. Ancient authors, like Lister, Müller, Chemnitz and Schröter, who have treated upon the terrestrial and fluviatile mollusks specially, have rarely mistaken these shells; and a mistake of this nature is very rare among modern authors, although a few instances might be cited. One can say only that the shells of terrestrial pulmonates are inoperculate, with entire apertures (holostomate), never nacreous, rarely spirally striated; but one cannot give a single character expressible by words, notwithstanding that all who have seen a certain number of species can distinguish them with facility. The fluviatile mollusks, nearly always unicolored, although they may resemble marine groups as to form, can also be readily separated at a glance.

Ferussac and several modern authors have thought that all mollusks inhabiting dry land respire by the aid of a pulmonary sack, but nothing is less certain. Among branchiferous genera, the Littorinas and many tropical Neritinæ, live a long while out of water. The larvæ of *Auricula* swim in the sea, and consequently possess a branchial respiration during this period of their life. According to Semper, *Ampullaria* has an accessory pulmonary sack. If the inoperculate pulmonates are considered, with so much reason, as an incontestable group, it is because, apart from their pulmonary sack, they possess other collateral characters of equal importance, as for example, the position of the eyes, the organization of the mouth and of the sexual organs.

The rest of the gastropods, after the exclusion of the pulmonates, were divided by Cuvier into several very natural groups, according to the form and position of the branchiæ (nudibranchs, heteropods, tectibranchs, scutibranchs, cyclobranchs). The magnificent work of Quoy and Gaimard is full of precious material for the amelioration of the great group of pectinibranchiates. The Trochidæ are here shown to be inseparable by their characters, as much external as internal, from Haliotis and other scutibranchs, notwithstanding the presence of an operculum and an elevated spire in the former. At the same time the great systematic value of the nacre was proved. *Stomatella*, with an animal similar to the Trochidæ, has a nacreous interior, whilst *Sigaretus*, with a non-nacreous shell, has an animal like *Natica*. The relations between the enamel of the shell of *Cypræa*, *Oliva* and *Natica*, and the structure of the animal were shown for the first time by the same work. As it has become evident to me that the presence of an operculum and the height of the spire, considered heretofore as prime characters, have, in reality, little value in distinguishing the families, I have sought to divine the natural affinities of mollusks according to the sculpture and structure of their shells.

In 1847, Lovén published four plates of lingual dentition, repre-

senting 94 species of cephalous mollusks. The first glance at these plates suffices to show clearly that the lingual armature confirms the most of the ancient divisions. Thus, the Cephalopods, Pteropods, Heteropods, Scutibranchs (in the sense of Quoy and Gaimard, including the Trochidæ), are also distinguished by the teeth. The conchological analogy between *Pleurotoma* and *Conus* had already been shown by Sowerby. There existed, nevertheless, certain anomalies until then inexplicable, on account of the small number of observations made, as for example, the analogy between *Philine* and *Scaphander* and the *Gymnobranchs*. The want of teeth must not be considered as fatal to the systematic value of characters found in these organs. The teeth accepted as an exclusive character have, doubtless, inconveniences, as in the whole animal kingdom, but it cannot be denied that all other organs taken as exclusive characters offer still greater inconveniences. Thus the shell may be wanting in very similar animals (for example, *Notarchus*, *Aplysia*; *Pterotrachea*, *Cardiopoda*; *Limax*, *Tebennophorus*). The operculum is often wanting in the adult, although the young may have it. There are even operculated and inoperculated species in the same genus, as understood by many modern authors (for example, *Pleurotoma* and *Bela*, *Oliva* and *Olivella*, *Yetus*, *Voluta* and *Lyria*, *Spirialis* and *Limacina*, *Proserpina* and *Helicina*). The organs of respiration and locomotion may be entirely wanting in closely related species (*Firoloidea* and *Phyllirhoë*).

Lovén has characterized the families according to the teeth, and has given Latin diagnoses. In 1848, Troschel (*Handbook of Zoology*) mentions the teeth as characters of all his suborders, and introduces into the nomenclature, for the first time, several new names taken from the form of the teeth. Thus the section *H.* of Lovén is called *Rhipidoglossa*, including the *Scutibranchs*, that is to say, *Neritidæ*, *Trochidæ*, *Haliotidæ* and *Fissurellidæ*. For the section *L.* of Lovén he proposed the term *Toxoglossa*. *Tænioglossa* corresponds to the *Ctenobranchous* *Gastropods*, having seven rows of teeth (3. 1. 3.), excepting the operculate *pulmonates*, although they may have the same form of teeth. Thus *Cyclostoma* is placed in another suborder from *Valvata* and *Paludina*. The *Heteropods*, which have the same general disposition of the teeth as *Tænioglossa*, are regarded as an order, with the same value as the *Gastropods*—an opinion still maintained by this author.

In 1853, Dr. Gray (*Proc. Zool. Soc.*, 32), in adopting the names of Prof. Troschel, proposed several new groups, according to the form of the teeth.

1. *Hamiglossa*. Three ranges of teeth (1. 1. 1), the lateral versatile. This last character appears to Prof. Mörch to be

consequent upon the rupture of the tissues; it is observed above all when there is abundance of water under the compressor.

2. Odontoglossa. Including only Fasciolaria, Mitra and Turbinella, which have the same form of teeth, but of which the laterals are not versatile.

3. Rachiglossa. A single row of teeth (0. 1. 0.); the laterals having disappeared.

4. Dactyloglossa. Only differing from Tænioglossa by their lateral teeth, which are wider, with very profound comb-like incisions.

5. Ptenoglossa. Teeth nearly subulate, in numerous longitudinal rows; Scalaria, Acteon.

6. Gymnoglossa. No teeth: Architectonidæ, Acusidæ, Cancelariadæ, Pyramidellidæ. But teeth have been since discovered in the three first families. There are, doubtless, many genera indubitably deprived of teeth, without, for that reason, forming separate groups.

Gray has regarded these different groups as having a systematic value inferior to that of the form of the proboscis. Thus he divides the Ctenobranchiates into two suborders: the Proboscifera, which he believes zoophagous, furnished with an entirely retractile trunk, and the Rostrifera, having a contractile, but not retractile, trunk, and sometimes very long, as in Struthiolaria, which he supposes phytophagous.

The author has thus placed the sections of Toxoglossa, Gymnoglossa, Ptenoglossa and Tænioglossa in these two suborders. The small value of the retractile trunk as an ordinal character is proved for example in the Bullidæ (*Bulla vexillum* possessing a very long retractile trunk). Odostomia has also a very long retractile trunk; and the rather short trunk of Janthina is very often retracted into the head.

In his Guide to the British Museum, 1857, Dr. Gray has reunited all the Toxoglossæ in a single division Toxifera, still retaining for the other divisions the separation into two widely removed sections. The name of Ctenoglossa is changed to Ptenoglossa; the name Trapezodonta is proposed for the Coriellæ, the teeth of which do not appear to Prof. Mörch to differ from the Tænioglossæ except in the want of the two internal teeth on each side (1. 0. 0. 1. 0. 0. 1.). Heteroglossa is proposed for the Cyclobranchiates.

In 1854, Mörch divided the cephalophora into five great groups, namely: I. Rhipidoglossata (including the Cyclobranchs); II. Ptenoglossata (Pulmonata, Tectibranchiata, Janthinidæ); III. Tænioglossata (including Pneumonopoma and Heteropoda); IV. Hamiglossata (Proboscidea of Troschel, Odontoglossa and Rachiglossa of Gray); V. Toxoglossata (including Pleurotoma

and Terebra. In 1857, Mörch reduced the five principal divisions to three, namely :

I. Musivoglossata (corresponding to the Ptenoglossata of 1856, but thus modified because this name has been used by M. Troschel to characterize the group of Janthinæ and Sclariæ), Pulmonata and Tectibranchia.

II. Arthioglossata, including: 1. Tænioglossata; 2. Ancistroglossata; 3. Toxoglossata.

III. Rhipidoglossata, with the section Orthodonta (Cyclobranchiates).

In 1861-2, circumstances having induced Prof. Mörch to study the Planarians, he was struck with their great affinity with the Pellibranchs, above all in the generative organs; this caused him to make a comparative revision of the genital organs of mollusks. He then ascertained that those belonging to his first division were androgynous and furnished with a retractile male organ; whilst those of the second section were diœcious, with a non-retractile male organ; and those of the third section differed from the others by the want of a copulative organ. In other words, he had thus arrived, independently, at the three groups proposed in accordance with the sexual organs by Blainville and Latreille.

In 1859, Mörch perceived that Mollusks were divided into two great groups, according to the construction of the heart and that these groups accorded also with those furnished by the sexual organs. Thus the Phanerogama, Latr., with a retractile or non-retractile copulative organ, have a heart with a single auricle (Monotocardia, Mörch), whilst the Agama, Latr., which have no copulative organ, have a heart with two auricles (Diotocardia, Mörch). It appears, doubtless, rather strange that the acephala should form a group with a considerable portion of the gastropods (Rhipidoglossa and Heteroglossa), but there exists a similar division among the vertebrates, namely: the cold-blooded vertebrates, where the fishes are united with reptiles, the latter provided with well-developed locomotive organs analogous to those of the mammalia.

Stimpson proposed (*Am. Jour. Sci.*, 2 ser. 37, p. 47, 1864), to form a group Anandria, characterized by the want of a male copulative organ. This group includes the Melanians of North America, the Vermetidæ and Turritellidæ and certain Cerithiæ. M. Rüppel, however, has figured a male organ in *Vermetus inopertus*, and M. Lacaze-Duthiers has found a single male individual which circumstances did not permit him to examine sufficiently. As to the Melanians, they may want an external conical male organ, but the sexual character is with them represented by a groove. In the Agama of Latreille there is not the least external sexual difference.

Mr. Mörch believes that naturalists of the most opposite schools could agree to a scheme of classification which he submits, as follows :

Sub-Kingdom 3.—MOLLUSCA.

Supra-class 1. PHANEROGAMA Latr. (Monotocardia, Mörch).

Class 1. ANDROGYNA (Hermaphrodita, Latr.).

Order 1. GEOPHILA, Fer (Stylommatophora, A. Schmidt .
Phyllopora with jaw. *Agnatha* without jaw.

Order 2. HYGROPHILA; eyes at the interior base of the tentacles.
Planorbis, Physa, Limnæa, Siphonaria, Ancylus, Auricula.

Order 3. TECTIBRANCHIA (Pomatobranchia), Pyramidella
(connecting with the preceding genus), Obeliscus, Odostomia, Chemnitzia, Actæon, Bulla, Aplysia, Notarchus.
Gasteropteron connecting with the Pteropods.

Order 4. PTEROPODA.

1. *Gymnosomata*. Clione, Pneumodermon.

2. *Thecosomata*. Clio, Hyalæa, Limacina, Heterofusus.

Order 5. GYMNOBRANCHIA.

1. *Pygobranchia*. Doris, etc.; branchiæ near the anus.

2. *Pleurognatha*.* Pleurophyllidia, Dendronotus, Tritonia,
Bornella, Æolis, Glaucus, Phyllirhæ.

Order 6. PELLIBRANCHIA. Tethys, Chioræa, Hermæa, Elysia,
Limapontia, Pelta.

All these mollusks are placed at the head of the gastropods by Cuvier. Messrs. Troschel and Gray arrange them between the Acephala and Patella, considering androgynism as probably a character of absolute inferiority; but the Acephala have generally separated sexes.

Class II. DIOICA, Latr. (Exophallia, Mörch).

Order 1. TÆNIOGLOSSATA, Troschel.

This is the only division where the family groups and their reciprocal relations do not appear to Mörch to be perfectly clear. In any case, it appears incontestable that all mollusks having seven ranges of teeth form a characteristic group. Recently, Troschel has divided the Tænioglossata into three groups according to the trunk :

1. Trunk not retractile.

2. Trunk retractile only by the end.

3. Trunk retractile from the base.

These differences appear to originate solely in the different length of the trunk. The old divisions Holostomata and Entostomata are not very faulty.

* Dr. Möbius has recently shown that the Doridæ have also lateral jaws, although very little developed.

Troschel's first section commences with the Pulmonates, but Mörch considers very doubtful their having a true pulmonary sack closed by a contractile opening. Gray calls these respiratory organs of the Cyclostomæ "gills vascular, branched," and "gills indistinct in the form of series of vessels on the inner surface of the mantle."

"Sect. 1. Fam. 1, Aciculacea; 2. Pomatiacea; 3. Cyclotacea; 4. Cyclostomacea.

Sect. 2. Respiring by branchiæ and lungs; Ampullariacea.

Sect. 3. Branchiferous Holostomata. Fam. 1. Valvatæ; 2. Hydrobiæ (Lithoglyphus); 3. Littorinidæ; 4. Rissoidæ; 5. Paludinidæ; 6. Melaniidæ; 7. Potamidæ; 8. Cerithiidæ (Planaxis).

The Aporrhaidæ form a passage between the Cerithiidæ and Strombidæ. Crepidula and Capulus belong with Hipponyx in a group, notwithstanding differences in the labial palpi. Onustidæ connects the Crepidulidæ with the Heteropods.

Ovulidæ (including Pedicularia), generally placed close to Cypræa, is strongly distinguished from the latter by its non-retractile proboscis. Notwithstanding this character, Mörch considers it intermediate between Cassis and Cypræa.

The 3d section of Troschel (trunk retractile from the base) contains the genera which Mörch united in 1852 in the family Tritonidæ, namely: Cassis, Dolium, Pyrula, Triton, Ranella.

Onchidiopsis, Velutina, Marsenia, Tyrodina, form, probably, a very natural division, notwithstanding the want of the two lateral teeth in Marsenia. The family Naticidæ stands next in relationship. It is in the Tænioglossata that the greatest incertitude relative to a natural grouping of the families exists; in the orders which follow, these relationships are more positively defined.

Order 2. RHACHIGLOSSATA, Troschel. Never more than three rows of teeth. All mollusks having coriaceous ovisacs, heretofore known, belong to this order.

Sect. 1. Marginella, Voluta, Volutilithes, connecting with Cryptochorda and Harpa; Oliva, Ancillaria, Bullia, Nassa, Mitra, Columbella.

Sect. 2. Buccinum, Fusus, Fasciolaria, Turbinella, Purpura, Murex, Magilus.

Order 3. TOXOGLOSSATA. Two rows of teeth. Stimpson has recently discovered a median tooth in *Clionella sinuata*, Born. Conus, (Borsonia?), Pleurotoma, Clionella, Terebra, Cancellaria, Halia, Lachesis?

Supra-class II. AGAMA, Latr. (Diotocardia, Mörch).

Mollusks without copulative organ. Heart with two auricles, placed nearly always around the intestine.

Class 1. EXOCEPHALA, Latr. (Pseudophallia, Mörch).

Order 1. RHIPIDOGLOSSA, Troschel. Proserpina, Helicina, Hydrocena, with sessile eyes.

Gray, in figuring the teeth of Proserpina (Ceres), formed for this mollusk a distinct suborder, alongside of the Neritinæ, which he called Pseudobranchia. In the same year (1857) Mörch placed Helicinæ in the Rhipidoglossates, with Neritina, notwithstanding the want of an operculum in Proserpina, an example followed by Troschel with some hesitation.

Eyes sessile. Shell not nacreous. Neritina, Nerita.

Shell nacreous. Phasianella, Turbo, Trochus, Margarita, Stomatia, Haliotis.

Eyes not petiolate. Shell not nacreous. ? Scissurella, Emarginula, Fissurella, the affinity of which with Haliotis, is incontestable.

Order 2. HETEROGLOSSATA, Gray. (Orthodonta, Mörch, Docoglossa, Troschel.) Patella, Tectura, Pilidium, etc., Chiton.

Class 2. ACEPHALA, Cuvier. (Endocephala, Latreille; Dithyra, Anst.)

Dimyaria (Plagymiona, Latr.).

Heteromyaria (Mytilacea).

Monomyaria (Mesomyona, Latr.).

Notwithstanding that the systematic value given above to these different groups varies from that of other authors, their order of succession differs but little from Cuvier. The separation of the Rhipidoglossata (Pectinibranchiates) and Scutibranchiates, is the principal change. The arrangements of Gray and Troschel differ still more, above all in the Androgyna, which are placed between the Heteroglossa and Acephala, probably because androgynism is considered as a character of inferiority; notwithstanding that the Acephala, which are inferior, have the sexes separate, with some exceptions. The little division, Ptenoglossa, including only Janthina, Scalaria, Solarium, is placed in the system of Troschel, between the Rhachiglossa and Rhipidoglossa. If we admit a special concordance between the teeth of these three groups, Mörch still does not consider the difference sufficient to justify a separation from the Androgyna. Janthina appears to him more close to the Pteropods by its lateral wings, and Scalaria, notwithstanding the position of the eyes, approaches Chemnitzia.

As in the entire animal kingdom, the greatest difference exists amongst authors relative to the value of the swimming organs. Latreille has united the Cephalopods and Pteropods in a single division Pterygia, to which he attributes the same value as to his Apterygia, comprehending all other mollusks. Gegenbauer

and Huxley have demonstrated that the Pteropods are veritable Gastropods furnished with a pair of accessory swimming organs. Already the discovery of Gasteropteron has shown the little value of the Pteropods as a division equivalent to the Gastropods. The Heteropods merit still less to be considered as a division of equal value.

The late Prof. O. A. L. Mörch, although attaching as much systematic value to the lingual dentition as any other conchologist, acknowledged that no single organ could be used in classification unless its differential characters accorded with differences of other portions of the animal and shell; but he endeavored to show that conchologists have erred in estimating too highly for systematic purposes the *form* of the shell, whilst neglecting other external characters, such as sculpture, structure (nacreous, porcellanous, etc.) and color. "According to my views, one must consider shells, so to say, from a mineralogical point of view." Having thus chosen conchological characters heretofore neglected, in grouping the genera and families, the discrepancies between a natural classification of the shells and one founded on dentition, according to Prof. Mörch, will disappear. "I have united in the family Tritonidæ, according to the sculpture, *Ranella*, *Triton*, *Pyrula* (*Ficus*), *Dolium*, *Cassidaria* and *Cassis*, placing them near to *Cypræa*." This is in accord with the character of their dentition, which widely removes *Triton* and *Ranella* from the Muricidæ, close to which they have heretofore been placed, upon conchological characters—principally the form of the shell, the presence of varices, the operculum, and also a decided resemblance of the animals.

I have carefully re-examined these genera and their relationships with others, in the point of view taken by Prof. Mörch, and the result of this examination is to convince me that he has selected in the sculpture a character that is of generic importance only in the single genus *Dolium*—that is to say, its species happen to possess revolving ribs; and even in sculpture the relationship of *Triton* and *Ranella* with *Murex* is exceedingly close, whilst they have little or no affinity with *Dolium*, *Cassis*, etc. In fact, it is precisely because Prof. Mörch has regarded lingual dentition *à priori* as an "infallible criterion" that he has been enabled to detect supporting resemblances in the shells. It is easy to show in many other instances, as in the group under discussion, how heterogeneous is the assemblage united by means of the "infallible criterion." There is, besides, a growing conviction, that there are no sharply-defined groups in nature; that a generic character, for example, cannot be made to cover all its species; that upon its borders occur forms which partake of the characters of other so-called genera, and that families, orders, etc.,

similarly coalesce upon their confines. We may anticipate a period when our larger collections, together with our better knowledge of external influences and of the power of adaptation to them of these creatures, shall reveal to us a series of recent and fossil forms having relationships so intimate, that our present system of classification and resulting nomenclature shall become utterly valueless.

In this point of view classification is essentially arbitrary and we can only help ourselves by choosing that which does least violence to natural affinities. The value of a classification founded on a single organ (the lingual ribbon), which does violence to other apparent affinities, whilst at the same time it fails of signification even in one of the most important functions with which it is connected, in that it does not enable us to certainly separate the phytophagous from the zoophagous animals, may be seriously questioned. We have many most important characters of the mollusks which impress themselves upon their shells, so that they are in accord and enable us to predicate reciprocally their relationships; and such characters appear to me to be much more useful for classification.

Mr. Wm. G. Binney, who has devoted a number of years to the study of the dentition and anatomy of terrestrial mollusks, has recently given the following guarded opinion upon the value of the jaw and lingual membrane for the purpose of classification.

"It is conceded by all recent students of land shells that for the larger divisions the presence or absence of a jaw and the aculeate or quadrate form of marginal teeth are reliable characters.

"The characters of the jaw and separate teeth of the lingual membrane have also been used in various ways for grouping the genera into families, etc., and even of grouping species into genera. I refrain from any discussion of their value for such purposes, simply because I believe our material is far too limited. It seems as if I can better employ my time in patiently accumulating new facts. I can, however, venture to say that the character of the jaw and teeth seems to be more constant in some genera than in others. It appears, for instance, that in some genera the presence or absence of lateral teeth is not a generic character, though in others it is. The same may be said of the presence or absence of side-cutting points to the centrals and laterals, and the greater or less development of their side cusps; also in the bifurcation or non-bifurcation of the cutting point of aculeate marginal teeth; also as to the presence or absence of ribs on the jaw.

"It will, I believe, be proved that certain genera are constantly characterized by a peculiar form of teeth, while others have a considerable range of variation. I might, perhaps, add that when the genus is numerous in species, there is a much greater

chance of finding a varying dentition. If this latter proves true, we shall be obliged to concede that there are certain types of teeth which may be found among the species of some of the larger genera, though some of the smaller genera are much more, if not absolutely restricted to one single type of dentition."

If it be proposed that a single arbitrary standard shall be used because it is arbitrary and hence will remove all doubt as to the position of a given species, then the standard selected should be the most universal and the most apparent—namely, the shell. But if a *natural* arrangement be attempted, still less can we make account of any character which is not in accord with the assemblage of characters. A natural sequence can only result from an accordance of most of the organs and functions. That dentition in the mollusks is a character worthy of study, that it will throw light on many doubtful points, that it will correct many errors is not to be disputed; but the claims made for it are preposterous;—for whilst a few hundred species only have had their tongues examined, described and figured, many thousands have been arbitrarily placed and displaced in consequence. Stimpson has examined the tongue of *Ranella caudata* and finds it to be that of a *Murex*; accordingly he separates from *Ranella* a few other species *because their shells resemble the shell of Ranella caudata* and unites them also with *Muricidæ* and this is practically the course (and necessarily so) pursued by all these dentition systematists. If conchological characters may be used to support the fabric reared upon the knowledge (I had almost written the want of knowledge) of a single structural character, why may they not be equally used against it. Is it not impertinent to make use of a few hundred observations of an organ which only pervades a portion of the mollusca, to establish a classification which is frequently in violent contrast with natural affinities ascertained by long examination of all the species, recent and fossil?

If the exo-skeleton or shell carries the impress of its animal, its right appreciation will afford us the *only possible* classification. It is not partial, but pervades nearly the whole mollusca—as well those which have no lingual ribbon; its universality is the proof of its higher systematic importance; its relationships are not single, it is the epitome of the modifications of molluscan structure. Supposing the dentition of all living forms to be examined (an impossibility), we are still confronted by the fossil shells, which absolutely refuse to be classified by any other than conchological characters. What shall we do with them? Shall we use for these 30,000 species obvious external, universal characters, yet discard these in the recent mollusca for the modifications of a partial character, the very slight observation of which has sufficed to show that it may not be predicated with

certainty from either the shell, operculum, external features, or anatomy of the animal?

Whilst I shall continue to find in the shell the usual characters for the discrimination of genera and families, I shall not refuse all the aid which I can obtain from the study of lingual dentition as well as from all other sources which may enable me to more rightly appreciate natural relationships, to correct error, to avoid it. For the present, I prefer to treat Triton and Ranella as transitional genera having many relationships with the Murices, but partaking in their dentition and in some other structural details in the characters of Cassis, Dolium, etc.

Prof. Theodore Gill published in 1871, under the auspices of the Smithsonian Institution an "Arrangement of the families of Mollusks," largely founded on their lingual dentition. Whilst this classification presents many features as novel as praiseworthy, reflecting the highest credit on the philosophical views and critical acumen of its author, it is, I think, equally unacceptable with those classifications heretofore proposed by European authors in which this character has been used as an exclusive guide. I reproduce Prof. Gill's arrangement:—

Arrangement of Families of Mollusks.

BY PROF. THEODORE GILL.

(The figures in brackets refer to the illustrations of lingual dentition in *this work*.)

CLASS. A. CEPHALOPODA.

ORDER 1. DIBRANCHIATA.

Suborder Octopodia.

(*O. littorales*.)

1. Cirrhoteuthidæ.

2. Octopodidæ (x, 1).

(*O. pelagici*.)

3. Philonexidæ.

4. Argonautidæ.

Suborder Sepiophora.

(*Oigopsidæ*.)

5. Cranchiidæ (including Loligopsidæ).

6. Chiroteuthidæ.

7. Onychoteuthidæ.

8. Ommastrephidæ.

(*Myopsidæ*.)

9. Loliginidæ (x, 2).

10. Sepiolidæ.

11. Sepiidæ.

12. Belosepiidæ.

13. Spirulidæ.

14. Belopteridæ.

15. Belemnitidæ.

ORDER II. TETRABRANCHIATA.

(Nautiloidea.)

- | | |
|---------------------|--------------------------|
| 16. Nothoceratidæ. | 17. Bathmoceratidæ. |
| 18. Trochoceratidæ. | 19. Nautilidæ (x, 3, 4). |
| 20. Hercoceratidæ. | 21. Gyroceratidæ. |
| 22. Lituitidæ. | 23. Phragmoceratidæ. |
| 24. Gomphoceratidæ. | 25. Cyrtoceratidæ. |
| 26. Orthoceratidæ. | 27. Ascoceratidæ. |

(Goniatitoidea.)

- | | | |
|-----------------|------------------|-----------------|
| 28. Clymeniidæ. | 29. Coniatitidæ. | 30. Bactritidæ. |
|-----------------|------------------|-----------------|

(Ammonitoidea.)

- | | | |
|-------------------|---------------------|---------------------|
| 31. Turrilitidæ. | 32. Ceratitidæ. | 33. Ammonitidæ. |
| 34. Scaphitidæ. | 35. Cryoceratidæ. | 36. Ancyloceratidæ. |
| 37. Hamitidæ. | 38. Ptychoceratidæ. | 39. Hamulinidæ. |
| 40. Toxoceratidæ. | 41. Baculitidæ. | 42. Baculinidæ. |

CLASS B. GASTROPODA.

Subclass Diœcia.

ORDER III. PECTINIBRANCHIATA.

Suborder Toxoglossa.

- | | | |
|--------------------|-------------------|--------------------|
| 43. Conidæ (x, 5). | 44. Pleurotomidæ. | 45. Melatomidæ. |
| 46. Haliidæ. | 47. Terebridæ. | 48. Cancellariidæ. |
| | 49. Admetidæ. | |

Suborder Rhachiglossa.

- | | | |
|-----------------|--------------------------|----------------------|
| 50. Cystiscidæ. | 51. Marginellidæ (x, 6). | 52. Volutidæ (x, 7). |
|-----------------|--------------------------|----------------------|

(Odontoglossa.)

- | | |
|--------------------------|---------------------|
| 53. Fasciolaridæ (x, 8). | 54. Mitridæ (x, 9). |
|--------------------------|---------------------|

(Duplohamata.)

- | | |
|---------------------------|----------------------------|
| 55. Melongenidæ (x, 18). | 56. Buccinidæ (x, 11, 12). |
| 57. Nassidæ (x, 13). | 58. Cynodontidæ (x, 10). |
| 59. Turbinellidæ (x, 14). | |

(Hamiglossa.)

- | | |
|---------------------------|----------------------------|
| 60. Turridæ. | 61. Olividæ (x, 15). |
| 62. Harpidæ (x, 16). | 63. Ptychatractidæ. |
| 64. Muricidæ (x, 17, 19). | 65. Columbelloidæ (x, 20). |

Suborder Tænioglossa.

(Group Rostrifera.)

- | | |
|-------------------------------|----------------------------|
| 66. Pomatiidæ. | 67. Cyclostomidæ (xi, 21). |
| 68. Cyclophoridæ. | 69. Pupinidæ. |
| 70. Aciculidæ. | 71. Truncatellidæ. |
| 72. Ampullaridæ (xi, 22, 23). | 73. Valvatidæ (xi, 24). |

- | | |
|--|--------------------------|
| 74. Viviparidæ (xi, 25). | 75. Assiminiidæ. |
| 76. Rissoellidæ. | 77. Pomatiopsidæ. |
| 78. Rissoidæ. | 79. Skeneidæ. |
| 80. Bythiniidæ. | 81. Fossaridæ. |
| 82. Littorinidæ (xi, 26). | 83. Pyramidellidæ. |
| 84. Eulimidæ. | 85. Styliferidæ. |
| 86. Ceriphasiidæ (Strepomatidæ, xi, 27). | |
| 87. Melanopidæ. | 88. Melaniidæ. |
| 89. Cerithiopsidæ. | 90. Cerithiidæ. |
| 91. Planaxidæ. | 92. Cæcidæ. |
| 93. Vermetidæ. | 94. Tenagodidæ. |
| 95. Turritellidæ. | 96. Trichotropidæ. |
| 97. Hipponicidæ. | 98. Capulidæ. |
| 99. Calyptræidæ. | 100. Neritopsidæ. |
| 101. Onustidæ. | 102. Strombidæ (xi, 28). |
| 103. Aporrhaidæ. | |

(Digitiglossa..)

- | | |
|-----------------------------|---------------------|
| 104. Pedicularidæ (xi, 29). | 105. Amphiperasidæ. |
|-----------------------------|---------------------|

Rostrum with invertible tip.

- | | |
|-------------------------|-------------------------------------|
| 106. Cypræidæ (xi, 30). | 107. Triviidæ (including Eratoïnæ). |
| 108. Marseniidæ. | 109. Velutinidæ. |
| 110. Naticidæ (xi, 31). | |

Group Proboscidifera.

- | | |
|--------------------------|------------------------|
| 111. Pyrulidæ. | 112. Doliidæ (xi, 32). |
| 113. Cassididæ. | 114. Ranellidæ. |
| 115. Tritonidæ (xi, 33). | |

Suborder Ptenoglossa.

- | | |
|------------------------------|-------------------------------|
| 116. Ianthinidæ (xi, 35). | 117. Solariidæ (xii, 39, 40). |
| 118. Sculariidæ (xi, 36-38). | |

ORDER IV. HETEROPODA.

- | | |
|---------------------------|-----------------------------|
| 119. Atlantidæ (xii, 41). | 120. Carinariidæ (xii, 42.) |
| 121. Pterotrachæidæ. | |

ORDER V. RHIPHIDOGLOSSA.

Suborder Podophthalma.

- | | |
|------------------------------|---------------------|
| 122. Hydrocænidæ. | 123. Stoastomidæ. |
| 124. Helicinidæ (xii, 43). | 125. Proserpinidæ. |
| 126. Neritidæ (xii, 44, 45.) | 127. Rotellidæ. |
| 128. Turbinidæ (xii, 47.) | 129. Liotiidæ. |
| 130. Trochidæ (xii, 46.) | 131. Stomatellidæ. |
| 132. Pleurotomariidæ. | 133. Scissurellidæ. |
| 134. Haliotidæ. | 135. Maclureidæ. |

Suborder Diceranobranchia.

- | | |
|-----------------------|------------------------------|
| 136. Fissurellidæ. | 137. Emarginulidæ (xii, 50). |
| 138. Bellerophontidæ. | |

ORDER VI. DOCOGLOSSA.

Suborder Proteobranchia.

139. Acmæidæ. 140. Patellidæ (xii, 51.)

Suborder Abranchia.

141. Lepetidæ.

ORDER VII. POLYPLACOPHORA.

142. Chitonidæ (xii, 52). 143. Chitonellidæ.

Subclass Pulmonifera.

ORDER VIII. PULMONATA.

Suborder Geophila.

(*Oculiferous tentacles invertible.*)

(*Agnatha.*)

144. Oleacinidæ (xiii, 56). 145. Streptaxidæ.
146. Testacellidæ.

(*Goniognatha.*)

147. Orthalicidæ (xiii, 58).

(*Holognatha.*)

148. Cyliindrellidæ. 149. Pupidæ.
150. Helicidæ (xiii, 59). 151. Vitrinidæ.

(*Togata.*)

152. Philomycidæ.

(*Subnuda.*)

153. Cryptellidæ. 154. Parmacellidæ.
155. Limacidæ (xiii, 61). 156. Arionidæ.

(*Elasmognatha.*)

157. Succinidæ (xiii, 63). 158. Janellidæ.

(*Oculiferous tentacles simply contractile.*)

159. Vaginulidæ. 160. Onchidiidæ.

Suborder Basommatophora.

(*Limnophila.*)

161. Chilinidæ. 162. Physidæ.
163. Ancyridæ. 164. Limnæidæ (xiii, 64-65).
165. Otinidæ. 166. Auriculidæ (xiii, 67).

(*Petrophila.*)

167. Siphonariidæ. 168. Gadiniidæ.

(*Thalassophila.*)

169. Amphibolidæ.

Subclass Opisthobranchiata.

ORDER IX. TECTIBRANCHIATA.

- | | |
|-------------------------------|-----------------------|
| 170. Philinidæ. | 171. Amphyspiridæ. |
| 172. Ringiculidæ. | 173. Actæonidæ. |
| 174. Actæonellidæ (xiii, 68). | 175. Cylichnidæ. |
| 176. Bullidæ. | 177. Aplustridæ. |
| 178. Lophocercidæ. | 179. Aplysiidæ. |
| 180. Runcinidæ (xiii, 70). | 181. Tylodinidæ. |
| 182. Umbrellidæ. | 183. Pleurobranchidæ. |

ORDER X. NUDIBRANCHIATA.

Suborder Pygobranchia.

- | | |
|---------------------|---------------------------|
| 184. Doridopsidæ. | 185. Dorididæ (xiii, 69). |
| 186. Onchidorididæ. | 187. Goniodorididæ. |
| 188. Polyceridæ. | 189. Triopidæ. |
| 190. Ceratosomidæ. | |

Suborder Polybranchia.

(Inferobranchia.)

- | | |
|-------------------|---------------------|
| 191. Phyllidiidæ. | 192. Diphyllidiidæ. |
|-------------------|---------------------|

(Polybranchia.)

- | | |
|-----------------|-----------------|
| 193. Tritonidæ. | 194. Scyllæidæ. |
|-----------------|-----------------|

(Ceratobranchia.)

- | | |
|--------------------|----------------|
| 195. Dendronotidæ. | 196. Heroidæ. |
| 197. Tethyidæ. | 198. Dotoidæ. |
| 199. Protonoctidæ. | 200. Glaucidæ. |
| 201. Eolididæ. | 202. Fionidæ. |
| 203. Hermæidæ. | |

Suborder Pellibranchiata.

- | | | |
|----------------|--------------------|---------------------|
| 204. Elysiidæ. | 205. Limapontiidæ. | 206. Phyllirrhoidæ. |
|----------------|--------------------|---------------------|

Suborder Entoconchacea.

- | |
|--------------------|
| 207. Entoconchidæ. |
|--------------------|

Subclass Pteropoda.

ORDER XI. THECOSOMATA.

- | | |
|------------------|-------------------------|
| 208. Limacinidæ. | 209. Hyalidæ (xii, 55). |
| 210. Cymbuliidæ. | 211. Conulariidæ. |
| 212. Hyolithidæ. | |

ORDER XII. GYMNASOMATA.

- | | |
|-------------------|----------------------------|
| 214. Clionidæ. | 215. Pneumodermonidæ (xii, |
| 216. Cymodoceidæ. | 53-54). |

Subclass Prosopocephala.

ORDER XIII. SOLENOCONCHÆ.

217. Dentaliidae.

CLASS C. CONCHIFERA.

ORDER XIV. DIMYARIA.

(Pholadacea.)

218. Aspergillidae.

219. Gastrochænidæ.

220. Teredinidae.

221. Pholadidae.

(Solenacea.)

222. Solenidae.

223. Solecurtidae.

(Myacea.)

224. Saxicavidæ.

225. Myidæ.

226. Corbulidae.

227. Pandoridæ.

228. Anatinidae.

229. Myochamidæ.

230. Pholadomyidae.

(Veneracea.)

231. Mactridæ.

232. Mesodesmidæ.

233. Amphidesmidæ.

234. Tellinidæ.

235. Psammobiidæ.

236. Donacidæ.

237. Petricolidæ.

238. Veneridæ.

239. Glauconomidæ.

(Corbiculacea.)

240. Cyrenidae.

241. Pisidiidæ.

242. Cyrenoididæ.

(Dreissenacea.)

243. Dreissenidae.

(Cardiacea.)

244. Veniliidæ.

245. Glossidæ.

246. Cardiidæ.

247. Adacnidæ.

(Chamacea.)

248. Chamidæ.

(Lucinacea.)

249. Lucinidae.

250. Ungulinidæ.

251. Erycinidæ.

252. Cyamiidæ.

253. Leptonidæ.

254. Galeommidae.

(Solemyacea.)

255. Solemyidae.

(Carditacea.)

256. Crassatellidae.

257. Carditidae.

(Naiades.)

258. Unionidae.

259. Iridinidæ.

260. Mycetopodidae.

(Muelleracea.)

261. Ætheriidæ.

262. Muelleriidæ.

(*Trigoniacea.*)

263. Trigonidæ.

(*Arcacea.*)

264. Nuculidæ.

265. Ledidæ.

266. Arcidæ.

ORDER XV. METARRHIPTÆ.

267. Tridacnidæ.

ORDER XVI. HETEROMYARIA.

268. Mytilidæ.

ORDER XVII. MONOMYARIA.

(*Aviculacea.*)

269. Pinnidæ.

270. Pteriidæ.

271. Vulsellidæ.

(*Pectinacea.*)

272. Spondylidæ.

273. Limidæ.

274. Pectinidæ.

(*Anomiacea.*)

275. Placunidæ.

276. Anomiidæ.

(*Ostracea.*)

277. Ostreidæ.

278. Eligmidæ.

ORDER XVIII. RUDISTA.

279. Hippuritidæ.

280. Radiolitidæ.

281. Caprinellidæ.

282. Caprinidæ.

283. Caprotinidæ.

Subbranch Molluscoidea.

CLASS D. TUNICATA.

(Families 284 to 298 inclusive.)

CLASS E. BRACHIOPODA.

ORDER XXIII. ARTHROPOMATA.

(*Ancylopoda.*)

299. Terebratulidæ.

300. Thecidiidæ.

(*Helictopoda.*)

301. Spiriferidæ.

302. Atrypidæ.

303. Koninckinidæ.

304. Rhynchonellidæ.

305. Strophomenidæ.

306. Productidæ.

ORDER XXIV. LYOPOMATA.

307. Craniidæ.

308. Discinidæ.

309. Lingulidæ.

CLASS F. POLYZOA.

(Families 310 to 356 inclusive.)

I propose to follow in this work a classification which does not differ very essentially from that most approved before the advent of the lingual system, but with certain ameliorations which the latter has enabled us to perceive for the first time. It is not denied that this arrangement is exceedingly artificial—all are so; but it is believed to be the most obvious, therefore, the easiest. It may again be remarked here, that one of the inherent difficulties of arrangement in a lineal line is caused by inter-relationships; thus, I have chosen to proceed from *Murex* to *Pupura*, then to *Fusus* and to *Buccinum*; yet the two latter groups are equally related to *Murex* and with one another, and the passage from one group to another is so gradual that the assignment of some of the out-lying forms to a genus is very difficult.

ON COLLECTING SHELLS.

Search for living mollusks is based upon knowledge of the habits of these animals. We call *stations* the particular circumstances surrounding the specimens collected, whilst *habitat* comprehends the geographical distribution of each species.

Marine Mollusks. “When the tide is at the lowest, the collector should wade among the rocks and pools near the shore, and search under overhanging ledges of rock as far as his arms can reach. An iron rake, with long close-set teeth, will be a useful implement on such occasions. He should turn over all loose stones and growing sea-weeds, taking care to protect his hands with gloves, and his feet with shoes and stockings, against the sharp spines of *Echini*, the back-fins of sting-fishes, and the stings of *Medusæ*. In detaching chitons and limpets, which are all to be sought for on rocky coasts, the spatula or case-knife will prove a valuable assistant. Those who have paid particular attention to preserving chitons have found it necessary to suffer them to die under pressure between two boards. Ormers (*Halio-*tides) may be removed from the rocks to which they adhere by throwing a little warm water over them, and then giving them a sharp push with the foot sideways, when mere violence would be of no avail without injuring the shell. Rolled madrepores and loose fragments of rock should be turned over; cowries and other shell-fish frequently harbor under them. Numbers of shell-fish are generally to be found about coral-reefs.”—(BRODERIP.) In coral regions the services of natives should be obtained, as they may render much assistance by diving or wading.

Advantage may be taken of spring-tides, especially at the equinoxes, to examine lower tracts of sea-shore than are ordinarily accessible. After severe storms the shores and beaches are frequently covered with species of mollusks and other marine

animals, seldom obtained at other periods except by the dredge. Many bivalves bury in sand and mud at extreme low-water, and may be obtained alive by digging with a spade or fork; others may be found boring in piles and rocks, and require the hammer and chisel for their extraction. Bivalves may be boiled, and their soft parts removed when the shells gape. Care should be taken not to injure the ligament, or hinge, especially in the genera (like the *Anatinidæ*) provided with an ossicle.

Mr. Joshua Alder remarks that "in collecting among rocks the principal thing is to look close, particularly in crevices and under stones. Minute species inhabiting sea-weed are best obtained by gathering the weed and immersing it for some time in a basin of sea-water, when the little mollusks will generally creep out. If the shells only are wanted, the surer and more ready way is to plunge the weed into fresh-water, when the animals immediately fall to the bottom." Sea-fishes and fowl purchased for the table should be carefully examined when opened for cleaning; shells are frequently obtained in this way:—which has furnished conchologists with many fine specimens.

The floating mollusca of the open sea, especially in tropical latitudes, are comparatively little known. Good drawings, and descriptions made from the life, are most valuable. "Of the animal of the *Spirula*, entire specimens are still greatly wanted. If captured alive its movements should be watched in a vessel of sea-water, to see whether it has the power of rising and sinking at will; its mode of swimming, and position during these movements, and when at rest. The chambered shell should be opened under water, to ascertain if it contain a gas, the nature of which should, if possible, be made out. The pearly nautilus requires the same observations, which would be attended with more precision and facility from its larger size."—(OWEN.)

The towing-net used by Mr. McGillivray "consisted of a bag of bunting (used for flags) 2 feet deep, the mouth of which was sewn round a wooden hoop 14 inches in diameter; three pieces of cord, $1\frac{1}{2}$ foot long, were secured to the hoop at equal intervals and had their ends tied together. When in use, the net was towed astern, clear of the ship's wake, by a stout cord secured to one of the quarter-boats, or held in the hand. The scope of the line required was regulated by the speed of the vessel at the time, and the amount of strain caused by the partially submerged net."—VOY. RATTLESNAKE.

A trawl-net for use on sea-bottoms is thus constructed: The side frames are of iron, the upper beam of wood, and the lower edge of the net is kept down to the ground by means of a chain, which is wolded or wrapped round with old rope. The beam is generally from 40 to 50 feet in length, and about 8 inches square. The net is about 30 yards in depth, and has a couple of pockets

inside. The end is untied when the net is hauled on board for the purpose of taking the fish out. These nets can only be worked where the bottom of the sea is free from rocks. They are used by boats of 35 to 60 tons, manned by crews of from four to six men and two to three or four boys. In the vicinity of Scarborough, England, they fish with these nets between the shore-reefs and the off rock, which is 4 to 10 miles from land; the bottom is sand or clay, with 4 to 15 fathoms water on the land side, and 17 to 25 fathoms on the off side. Immense quantities of crustacea and shell-fish are taken with the trawl, as well as ground-fish.

Kettle-nets. On the flat, sandy coast of Kent and Sussex, England, mackerel-fishery is pursued by setting up stakes 10 or 15 feet high, at distances of 10 feet apart, in lines running outwards from the shore at high-water, to low-water neap tides, where they are turned in the direction of the tide. To these stakes nets are attached, and leaded, which remain as long as the fish are on the coast. Cuttle-fish are frequently taken in these nets.

Deep-sea Fishery. In North Britain an extensive ground-fishery is conducted by means of long lines—often a mile in length—with hooks and baits every few yards. These lines are laid out at night near the coast, and taken up the next morning. When used out at sea, the boats lay by for a few hours, and then take up the lines. The carnivorous whelks adhere to the baits (which have not been seized by fishes), and sometimes a bushel of them are taken in this way from a single line. *Rhynchonella psittacea*, *Panopæa Norvegica*, *Velutinæ* and some of the scarce *Fusi*, have been obtained from these lines, the bivalves having been entangled accidentally by the hooks.

For trapping whelks on rocky ground a net may be made such as is used for crabs and lobsters, by attaching a loose bag to an iron ring of a yard across. This is fastened to a rope by three equal strings, baited with dead fish, and let down from a vessel at anchor, or, still better, from a buoy. It is put down over night, and hauled up gently in the morning.

Carnivorous mollusks are often found in lobster-pots, which they enter to feed upon the bait.

Dredging. "Up to the middle of last century the little that was known of the inhabitants of the bottom of the sea beyond low-water mark, seems to have been gathered almost entirely from the few objects found thrown upon the beach from time to time after storms, and from chance captures on lead-lines, and by fishermen on their long-lines and in trawls and oyster and clam dredges.

"The naturalist's dredge does not appear to have been systematically used for investigating the fauna of the bottom of

the sea, until it was employed by O. F. Müller in the researches which afforded material for the publication in 1799, of his admirable 'Descriptions and History of the Rarer and Less-known Animals of Denmark and Norway.' In the preface of the first volume Müller gives a quaint account of his machinery and mode of working which it is pleasant to read.

"The instrument usually employed for dredging oysters and clams is a light frame of iron about five feet long, by a foot or so in width at the mouth, with a scraper like a narrow hoe on one side, and a suspending apparatus of thin iron bars which meet in an iron ring for the attachment of the dredge rope on the other. From the frame is suspended a bag about two feet in depth, iron chain netting, or of wide-meshed hempen cord netting, or of a mixture of both.

"Naturalist dredgers first used the oyster dredge, and all the different dredges now in use are modifications of it in one direction or another; for in its simplicity it is not suitable for scientific purposes. The oyster dredge has a scraper only on one side. In the skilled hands of the fishermen this is no disadvantage, for it is always sent down in such a way that it falls face foremost; but philosophers using it in deep water very generally found that whether from clumsiness or from want of sufficient practice, they had got the dredge down on its back and of course it came up empty. Again oyster dredgers are only allowed to take oysters of a certain size, and the meshing of the commercial dredge is so contrived as to allow all bodies under a certain considerable size to pass through. This defeats the object of the naturalist, for some of the prizes to which he attaches the highest value are mites of things scarcely visible to the unaided eye.

"The remedy for these defects is to have a scraper on each side, with the arms attached in such a way that one or the other of the scrapers must reach the ground in whatever position the dredge may fall; and to have the bag deeper in proportion to the size of the frame, and of a material which is only sufficiently open to allow the water to pass freely through, with the openings so distributed as to leave a part of the bag close enough to bring up the finest mud.

"The late Dr. Robert Ball, of Dublin, devised the modification which has since been used almost universally by naturalists under the name of "Ball's Dredge." The dredges on this pattern used in Great Britain for ten years after their first introduction about the year 1838, were usually small and rather heavy—not more than from twelve to fifteen inches in length by four to five and a half inches in width at the mouth. There were two scrapers the length of the dredge-frame and an inch and a half or two inches wide, set at about an angle of 110° to

the plane of the dredge's mouth, so that when the dredge was gently hauled along it took hold of the ground and secured anything loose on the surface. I have seen Dr. Ball scatter pence on the drawing-room floor and pick them up quite dexterously with the dredge drawn along in the ordinary dredging position.

"Latterly Ball's dredges of considerably larger size have been used. Perhaps the most convenient form and size for dredging from a row-boat or a yawl at depths under a hundred fathoms, has a frame eighteen inches long, and its width is five inches. The scrapers are three inches wide, and they are so set that the distance between their scraping edges is seven inches and a half. The ends of the frame connecting the scrapers are round bars of iron five-eighths of an inch in diameter, and from these two curved arms of round iron of the same thickness, dividing beneath into two branches which are attached to the ends of the cross-bars by eyes, allowing the arms to fold down over the dredge-mouth, meet in two heavy eyes at a point eighteen inches above the centre of the frame. The total weight of the dredge frame and arms is twenty pounds. It ought to be of the best Lowmoor or Swedish wrought-iron. I have seen a stout dredge frame of Lowmoor iron twisted like a bit of wax in extricating it from a jam between two stones, and, singularly enough, the dredge which came up in that condition contained the unique example of an echinoderm never found before or since.

"The thick inner edges of the scrapers are perforated by round holes at distances of about an inch, and through these strong iron rings about an inch in diameter are passed, and two or three like rings run on the short rods which form the ends of the dredge frame. A light iron rod bent in the form of the dredge opening usually runs through these rings, and to this rod and to the rings the mouth of the dredge base is securely attached by a stout cord or strong copper wire.

"In the dredge now before me, which has worked well and seen good service, the bag is two feet in depth, and is of hand-made net of very strong twine, the meshes half an inch to the side. So open a network would let many of the smaller things through, and to avoid this the bottom of the bag, to the height of about nine inches, is lined with "bread bag," a light open kind of canvas.

"Many other materials have been used for dredge bags: one which I have used frequently is made of sail-cloth, with a window of strong brass-wire gauze let in on either side. Nothing, however, seems to me so good as strong cord netting. The water passes easily through and carries with it a large part of the fine mud, while enough mud is retained by the bread-bag lining in the bottom to give a fair example of its contents. It may be

said that many small valuable objects may be washed through the meshes of the upper part of the dredge along with the mud, and thus lost; but on the other hand, if the bag be very close it is apt to get filled up with mud at once, and to collect nothing more.

"It is always well when dredging, at whatever depth, to ascertain the approximate depth with the lead before casting the dredge; and the lead ought always to be accompanied by a protected thermometer; for the subsequent haul will gain greatly in value as an observation in geographical distribution if it be accompanied by an accurate note of the bottom temperature.

"For depths under a hundred fathoms the amount of rope paid out should be at least double the depth. Under thirty fathoms, where one generally works more rapidly, it should be more nearly three times. This gives a good deal of slack before the dredge if the boat be moving very slowly, and keeps the lip of the dredge well down; and if the boat be moving too quickly through the water, by far the most common error in amateur dredging, from the low angle at which the line is lying in the water, the dredge has its best chance of getting an occasional scrape. It is bad economy to use too light a rope. For a dredge such as that described, and for work round the coasts, at a depth attainable from a row-boat or yawl, I would recommend bolt-rope of the best Russian hemp, not less than one and a half inches in circumference, which should contain from eighteen to twenty yarns in three strands. Each yarn should bear nearly a hundred-weight, so that the breaking strain of such a rope ought to be upwards of a ton. Of course it is never voluntarily exposed to such a strain, but in shallow water the dredge is often caught among rocks or coral, and the rope ought to be strong enough in such a case to bring up the boat, even if there were some little way on.

"Dredging in sand or mud, the dredge rope may simply be passed through the double eye formed by the extremities of the two arms of the dredge; but in rocky or unknown ground it is better to fasten the rope to one of the eyes only, and to tie the two eyes together with about three or four turns of rope yarn. This breaks much more easily than the dredge rope, so that if the dredge gets caught it is the first thing to give way under a strain, and in doing so it very often so alters the position and form of the dredge as to allow of its extrication.

"The dredge is slipped gently over the side or stern—in a small boat more generally the latter—while there is a little way on, and the direction which the rope takes indicates roughly whether the dredge is going down properly. When it reaches the ground and begins to scrape, an experienced hand upon the rope can usually at once detect a tremor given to the dredge

by the scraper passing over the irregularities of the bottom. The due amount of rope is then paid out, and the rope hitched to a bench or pollock-pin.

“When there is anything of a current, from whatever cause, it is usually convenient to attach a weight varying from fourteen pounds to half a hundred-weight, to the rope three or four fathoms in front of the dredge; this prevents, in some degree, the lifting of the mouth of the dredge. If the weight be attached nearer the dredge, it is apt to injure the delicate objects passing in.

“The boat should move very slowly, probably not faster than a mile an hour. In still water, or with a very slight current, the dredge of course anchors the boat, and oars or sails are necessary; but if the boat be moving at all it is all that is required. I like best to dredge with a close-reefed sail before a light wind, with weights, against a very slight tide or current; but these are conditions which cannot always be commanded. The dredge may remain down from a quarter of an hour to twenty minutes, by which time, if all things go well, it ought to be fairly filled.

“In dredging from a small boat the simplest plan is for two or three men to haul in; hand over hand and coil in the bottom of the boat. For a large yawl or yacht, and for depths beyond fifty fathoms, a winch is a great assistance. The rope takes a couple of turns round the winch, which is worked by two men, while a third takes it from the winch and coils it.

“Dredging in deep water—that is, at depths beyond 200 fathoms—is a matter of some difficulty, and can scarcely be compassed with the ordinary machinery at the disposal of amateurs. Deep-sea dredging can no doubt be carried on from a good-sized steam yacht, but the appliances are so numerous and so bulky, and the work is so really hard, that it is scarcely compatible with pleasure-seeking.”—WYVILLE THOMSON, “The Depths of the Sea.”

In the valuable and interesting work above quoted (p. 246), may be found a full description, with figures, of the apparatus used in deep-sea dredging by the *Porcupine*. That vessel, on July 20th, 1870, dredged no less than 186 species of mollusks at a single haul, off the coast of Portugal, and from the great depth of 994 fathoms. Nearly forty per cent. of these were of undescribed species! “This remarkable collection,” says Wyville Thomson, “of which not much more than one-half is known to conchologists, notwithstanding their assiduous labors, teaches us how much remains to be done before we can assume that the record of marine zoology is complete. Let us compare the vast expanse of the sea-bed in the North Atlantic with that small fringe of the coast on both sides of it which has yet been partially explored, and consider with reference to the dredging last-

mentioned what are the prospects of our ever becoming acquainted with all the inhabitants of the deep throughout the globe!"

Equally important results, have attended the more recent dredging operations of the United States Fish Commission's *Fish Hawk*, southeast of Rhode Island, adding several hundred species to our fauna.

The reader of these pages, if possessed of a salt-water aquarium, is earnestly recommended to study marine mollusks in the living state. A judicious observer will not only derive much pleasure thereby, but may also contribute to our knowledge of the habits of these interesting animals. But few of the species have been intelligently studied in this manner, and it is almost certain that very much is to be learned by the use of this method of investigation.

Land and Fresh-water Shells. The following directions for collecting and preserving these, are principally compiled from papers by Prof. A. G. Wetherby (Jour. Cincin. Soc. Nat. Hist.), and Dr. James Lewis (Smithsonian Report, 1866).

Before the collector can enter the field with much certainty as to the anticipated result of his labors, it may be necessary for him to satisfy himself that there are in the district about him shells enough to offer encouragement. It will be found generally, that those sections of the country that have a dry sandy soil are unfavorable to the production of mollusks. Regions in which pines abound are proverbially of this character, and here the efforts of the collector are usually but indifferently rewarded. In the moist alluvial soil of limestone formations are found the most favorable conditions for the production of mollusks. This is more notably true with regard to land shells; aquatic species are also affected similarly, but less conspicuously, by the character of the soil. But it will almost invariably be observed that waters deficient in lime do not produce shells as perfect nor in as great numbers as waters charged with that earth.

Land Shells. With a few exceptions, relating to some of the smaller species and also a few species of semiaquatic habits, the land shells of this country are found most abundantly in the wooded alluvial regions, especially upon hill-sides having a northern exposure; where, during the day they are concealed under fragments of fallen trees, bits of bark, chips, etc., sometimes under leaves or in the tufts of rank growths of moss. Some species will be occasionally found in the moist debris of shaly rocks in ravines. Species peculiar to the Southern States are sometimes met with on shrubs and trees. Some species of semiaquatic habits, though occasionally seen on the rank vegetation along rivers (sometimes several feet from the ground), are more frequently observed under bits of wood, leaves, etc., near the muddy slopes of streams or ponds, or in the vicinity of

water, where they may find concealment either in grass or under the shade of aquatic plants.

Among our most minute species are those that delight in wet grass lands, or in localities that are usually moist during a very considerable portion of the year. They are sometimes found in such localities congregated in hundreds under stray fragments of boards, bits of wood, etc.

As different sections of the country offer constantly varying conditions affecting the habits of land shells, it may be expected that some species that usually are found in such stations as have just been indicated may in exceptional instances be found under circumstances where the collector might least hope to discover them. It accordingly becomes the collector to be at all times on the alert, and to inspect every kind of station. By doing so, he will often unexpectedly discover desirable species and acquire information respecting their habits, of more value to him than any suggestions that might be conveyed to him by a volume of printed instructions.

As examples it may be stated that in and around dilapidated buildings, where fragments of brick and mortar cover the ground, large numbers of the smaller species of *Helix*, *Pupa*, *Carychium*, etc., will be found. They adhere to the under surface of a piece of porous brick in preference to a fragment of gneiss, limestone or other rock. Also the cavity of a decayed tree or stump, when examined in the early days of spring, will reward the searcher abundantly. Rich harvest may also be frequently gathered by laying boards upon the grass or ground, wetting them previously unless immediately after a rain. In taking them up after a night's exposure large numbers of shells will often be attached to the under surface.

Fresh-water Shells. While searching for those species of land shells that are found usually near water, the collector will often have his attention drawn to air-breathing mollusks that are properly designated aquatic mollusca. The habits of some species of this class are such that by one unacquainted with them they might be confounded with land-shells. Many of these species have a habit of crawling out of the water, remaining on the moist mud without any inconvenience. They will also sometimes be found on the stems and leaves of aquatic plants, or on other projecting substances several inches from the surface of the water. In their habits as a class they are adapted to a wide range of conditions, so that they will be found in lakes, ponds, rivers, canals, ditches, stagnant pools, swamps, and small rivulets, though some species appear to be adapted to a narrow range of conditions; the class, however, has its representatives over the whole continent. Though by far the greater number of species of mollusca belonging to this class prefer shallow water, feeding

on the vegetation that abounds in such stations, there are a few exceptions, in which species are found adapted to deep water, in which it is improbable that they can reach the surface and respire the air. The collector will find many species accessible to him along the margins of water. Others will require the aid of a boat, especially such as are found feeding on the weeds in lakes and rivers. To discover some of the minute species found under such circumstances, it may sometimes be advantageous to gather handfuls of the weed and gently lift them out of the water. If the operation be rudely performed, the mollusks may be disturbed so as to detach themselves. Many species will be found adhering to the grass-like plants that grow in streams. Others adhere to the stems of flags and bullrushes, and may be discovered very readily by pulling up the plants by the roots, taking care to perform the operation gently and deliberately. Of analogous habits with some of the above are certain small species found concealed under stones just below low-water mark in rivers. They are sometimes also found adhering to larger shells. This class embraces only small cup-like shells—"fresh-water limpets" or *Ancylus*.

Aside from the air-breathing aquatic mollusca, we have others whose respiration is strictly aquatic; the necessities of these restrict them to a narrower range. Hence they are not usually found in stagnant waters, certainly not in waters of limited area, where impurities are generated by decomposing substances. The largest shells of this class are found in the swamps along the rivers of some of the Southern States, and are objects of interest on account of their habits as well as of their value in the cabinet. In their season of active life they are found feeding on aquatic plants. Inhabiting localities subject to drying, they burrow in the mud as the water diminishes. The collector will for convenience seek them when they are active. Another class (*Viviparidæ*), smaller than that just mentioned, but affording a greater number of varieties and species, is more widely distributed, being found not only in the waters of the various States, but also in Canada. They inhabit rivers, lakes, ponds and canals, and when circumstances favor their habits they will be found most abundantly burrowing just beneath the surface of the soft mud near the shores: where undoubtedly they are attracted by more abundant supplies of food, and perhaps also by a more agreeable temperature. They will often be found in the muddy banks of rivers in great numbers, congregated at the margin of the water. In canals where conditions of food and temperature are very favorable, they attain a more luxuriant growth than in neighboring rivers. Some localities are remarkable for affording varieties and monstrosities. Next to this class in size is one that embraces a large number of species included in several genera and sub-

genera (*Strepomatidæ*). The shells vary from a turritid to a globular form, variously colored and sometimes curiously ornamented with tubercles, ridges and carinations. With a few exceptions these interesting shells are found only in rivers or perennial streams. The different genera of this class seem to be adapted to certain modifications of conditions. Some of these mollusks prefer muddy sloping river-banks, where they crawl in the comparatively still water on the surface of the mud. Others prefer the rapid current among the rocky portions of streams, where they are found adhering to the surfaces of the rocks. The habits of nearly all the mollusca of this class are such as bring them to the shallower portions of the water they inhabit. They can often be reached from the shore by the hand.

By gradual transitions these genera, with their numerous species, are followed by other and smaller genera (*Amnicolidæ*, etc.), some of which are of comparatively limited range; others are widely distributed over the whole country. Nearly all of them have habits in some respects similar to the preceding class, and will be found on the muddy bottom portions of rivers, lakes, etc., or feeding on aquatic plants. The small size of many of these shells renders them somewhat difficult to discover, unless the collector has expedients for securing them with ease and certainty.

Bivalve Shells. These next claim our attention, and for convenience they will be considered under two classes, though embracing several distinct genera and species. A class of shells, none of which ever attain dimensions much exceeding half an inch (*Cyclades*), inhabit nearly every perennial stream having a muddy bottom; found also in stagnant waters, lakes, ponds, canals, and, indeed, in every station fitted for molluscan life. Some species inhabit stations subject to drying during a portion of the year, and careless observers have been deceived on finding them alive in their dried habitat, and have inferred they were bivalve land shells! All the shells of this class burrow just beneath the surface of the mud, and are usually found in greatest abundance near the margin of the water or where there is but little depth. This class embraces some species remarkable for their fragility, others equally remarkable for their minuteness. They are distributed over all the explored portions of the country.

Fresh-water mussels (*Unionidæ*.) This class of shells embraces several genera, which, on account of the great number of species contained in them will eventually be more minutely classified in subgenera. No country in the world has produced as great a variety of forms of *Unionidæ* as the United States. In the northeastern portion the number of species is comparatively small, but in the South and West the number of species

becomes great, and the variety and beauty discoverable in the almost endless varieties make this class one of great interest to the collector. These mollusks inhabit lakes, rivers and canals. Stagnant water is unfavorable to them. They afford abundant food for muskrat and mink, who collect piles of shells on the shore where they bring the mollusks to feed upon them. The shells left by the muskrat sometimes serve as a resort for the collector who is not critical to have the best of specimens, while they should serve to point out to him that there are good specimens, alive, not far distant. Except in shallow portions of rivers it is sometimes difficult, however, to find mussels; but where the water is not so deep but that a person may wade in it with security, it is comparatively easy to discover them. They will usually be found partly buried in the mud or gravel, only enough of the shell projecting to enable the mollusk to extend the siphons of his breathing apparatus into the water above him. A little practice will enable the collector to detect the projecting shell. In lakes and ponds, where the water is not too deep, the collector may readily discover the objects of his search from a boat.

Having thus in general terms given such suggestions as will enable the collector to seek shells understandingly, it will now be proper to speak more particularly of collecting. It may be doubted whether there is really such a thing as a "rare" species. The fable continually disappears in reference to forms once so considered. Hence intelligence and good judgment will usually enable a persevering collector to obtain a reasonable number of examples of any object to be found in his region, belonging to recent fauna and flora. The following rules of action are essential:—

1. Never rest satisfied until you have found the best examples of a species which your time and opportunities will allow.
2. Never collect imperfect or immature specimens, unless they exhibit some character making such a step desirable.
3. Having found a station which produces the finest specimens, study it carefully, that you may the more easily recognize such surroundings again.
4. If specimens are abundant collect plenty, and the work on that species will be done at once, save as you meet with desirable varieties.
5. Remember that if your specimens are good and clean, it will always give you an advantage in exchanges as soon as correspondents begin to recognize this fact. Never pick up a poor specimen with the remark, "this will do for exchange," if a good one can possibly be had.

Land Shells. The only apparatus needed in the field is the following:—One or two small bottles, 1 oz. and 2 oz., half filled

with a mixture, two-thirds best alcohol and one-third water and well corked. If these bottles are flattened oval, they may be carried in waistcoat-pockets, and will always be convenient of access.

A pair of dissecting forceps, of medium size. These will be found useful in picking up loose small shells, in taking them from crevices in bark, old logs, etc. The point of a pen-knife answers equally well if skilfully handled. This is a "knack" to be acquired by practice.

Two or three flattish boxes, of different sizes, that will readily slip in and out of the coat-pockets.

A rake made as follows: Having a head made of good oak or hickory, about nine inches long, and one inch by one and a half inches. In the centre make an oval hole for the handle, one inch long and one-half an inch or more wide. Put two blunt teeth, each two and a half inches long, exclusive of the part in the head, on each side of the handle, so placing the holes bored to receive them as to make the space between the teeth equal. Make the teeth of the toughest seasoned hickory. Make of the same material, a smooth, straight handle, twenty inches long, with one end exactly fitted to the hole in the head. This end should project through the head at least three-fourths of an inch. It should be bound by a narrow ferrule, so set into the wood as to permit the handle to slip into the head readily. A hole for a small steel spring-key should be made between the ferrule and the rake-head, and so close to each that the key, when in place, shall rest against the ferrule on one side and the rake-head on the other. When not in use the rake can be taken apart by withdrawing the key, and the whole implement can be carried in the coat-pockets. This instrument is indispensable; with it a hill-side may be rapidly raked over, or any other ground inhabited by land-shells, and, if the hands are covered by buck-skin gloves, briar-patches and other forbidding localities may be explored, and they are often very productive. As much surface can be worked over, with this implement, in half an hour, with perfect comfort and cleanliness, and without injury to the hands, as in half a day using the fingers only, and regions can be examined that it would be impossible to explore without it.

A small tool, made like a hatchet, with a narrow blade at one end, and somewhat hooked and pointed at the other, after the fashion of a geologist's pick, is very convenient for picking and hacking in pieces old logs, cutting away brush, pulling over stones, etc. No other tools are necessary or even desirable.

Being provided with these implements, you have only to sally forth, and with perseverance you will succeed in finding whatever a given locality is likely to produce. Having found the specimens, transfer all the smaller ones to the alcohol. Shells of

Stenotrema can be cleaned by removing the animal, but these and all shells below them in size, except the *Succineas*, should be dropped into the alcohol. Naked mollusks (snails or slugs) should be placed in a separate collecting bottle of alcohol, because of the mucus which they so plentifully shed. After death, when they have become somewhat stiffened, this mucus may be readily removed from their bodies with clean water. They are most conveniently preserved in alcohol. The larger species of land shells may be dropped, promiscuously, into the collecting boxes mentioned above. When a sufficient number of specimens has been secured, they must be cleaned and prepared for the cabinet. The following tools are necessary:

A few hooks of annealed wire, of different sizes and lengths. Take any piece of such wire, put a short, pine handle of suitable size on one end, and file the other to a somewhat slender point. These are used for drawing the snails out of their shells. They will hold better if you bend the point into a small hook.

Two or three brushes of different sizes.

A test-tube, five or six inches long, and half an inch in diameter, and a pint of perfectly clean white sand. A syringe; a rubber one, an inch diameter in the barrel, and six inches long, with a small nozzle aperture, is the best.

A small strainer, such as is used for tea or coffee; and a shallow pan, say two inches deep, and six inches in diameter.

Let us begin with the larger snails and wash every one clean. Have your pan of hot water on the stove, your unclean shells and implements all handy on a low table near by. Put two or three or half a dozen if you are tolerably sure of success, into your strainer, to which a wooden handle has been fixed. Set it with the shells into the hot water, and allow it to remain for a minute or less. Life is out, and taking one of the specimens in your left hand, between the thumb and fore-finger, hook one of your wire implements into the animal, making a gentle effort to withdraw it. If it comes out readily, draw out the others and throw them into a dish of clean, tepid water. If the animals cannot be withdrawn readily, scald them again for a short time. They will usually come out easily enough, but certain species cannot be withdrawn if scalded too much. These are matters of experience and will be learned by perseverance. Shells that you cannot at first succeed with, on account of irregularities in the aperture, small size, etc., will be mastered after awhile. Having withdrawn the animals wash the shells again thoroughly on the outside, and syringe them *thoroughly* inside, shake out the water and lay them on a newspaper to dry, mouth downward. The specimens thus prepared will be perfect, clean, and a delight either for study or exchange. The small shells remain to be looked after. If they are clean, leave them in the alcohol for a

day or two, then take them out, dry and assort them, and put them in their proper receptacles. But *Pupas*, *Vertigos*, and the small *Helices* are generally dirty. They may be perfectly cleaned in the following simple manner:

Put all you have of one species into the test tube. Put in with them a small quantity of the clean sand, say one-fourth or one-fifth what the tube will contain. Fill it with water, and shake very gently. As the sand removes the dirt, turn out the dirty water and fill with clean. In a few moments judicious care will clean such shells perfectly, and not damage them in the least. When clean, turn water, sand and all into a saucer, put in a little more water, shake all gently, and the sand will go to the bottom, while the little concentric wavelets will gather all the shells into a small space in the centre, whence they may be removed with a spoon or any convenient instrument. Pour off the water, dry your sand and put it away for future use. *Never use any acid or oil about land shells*, unless the tiniest amount of the latter on the too often eroded apices of burrowing species. Remember this caution, and always act upon it. Each species when cleaned and thoroughly dried should be accurately labeled with name, author, locality, and date of capture—if the locality is one seldom visited. The little boxes or tubes containing the smaller species should be kept in a larger box, the *Pupas* together, *Vertigos* together, etc. This will reduce the labor of selecting exchanges more than one-half.

Fresh-water Shells. The following implements are needed: Brushes, as before, but one or two larger and stiffer ones for the *Unionidæ*.

A scoop made of wire gauze, fine enough to hold the smallest shells, with a socket for the handle. This scoop should be hemispherical, eight inches in diameter, with the rim made of good, tough hoop iron, to which the socket is attached.

The handle may be used for a walking-stick, and the scoop can be carried in your basket. Both socket and handle must have a hole for the spring-key. A quart or two of saturated solution of oxalic acid. A small quantity of nitric acid. A bottle of boiled linseed oil. Bottles of alcohol, diluted somewhat, say one-fourth water. A few tin boxes of various sizes. These are all the necessary tools.

Having reached your locality, if the bottom is muddy, or sandy, and you are seeking for *Sphærium*, *Pisidium*, the *Amnicolidæ*, etc., usually found in such stations, put your handle into the scoop, slip the spring-key into its place, and scoop up mud, sand and shells, by a dragging motion along the surface. When the scoop is sufficiently filled, shake it in the water, washing out the mud and finer sand. Pick out the sticks and leaves, and continue this operation until your shells are easily removed.

Put the little univalves into alcohol. The smaller Pisidium and Sphæriums may also go there. The larger Sphæriums may be treated as hereafter described.

By this means if you do not hesitate to wade in the mud once in awhile, you can very rapidly collect all that you will need of such species from a given locality. The same implement can be used for skimming Planorbis, Physa and Limnæa from the surface, or for collecting them from the bottom when crawling there. These shells should be taken home in the boxes. If you are collecting in southern streams, where the various genera of the Strepomatidæ abound, no plan is so expeditious as the judicious use of the scoop. In some cases hand-picking must be resorted to, as these creatures live on the under sides of stones, in rock crevices, and among the gravel and pebbles at the bottom of streams, where they cannot otherwise be reached.

Gather these all into alcohol. It is not necessary to extract the animals; if they are taken out, dried and cleaned, as will be described, they will be in prime condition. If to the alcohol a quantity of arsenic be added, the larvæ of Dermestes and Anthrenus will not afterwards infest them. In hunting for freshwater univalves every kind of station should be explored. In mountain regions, springs, creeks, rivulets, small ponds, and larger streams will all have their characteristic genera, species and varieties, and all need to be thoroughly worked up.

The Unionidæ may be taken with a pair of spoon-tongs, worked from a row-boat; but for these mollusks it must be admitted that no other plan is equal to wading into the water, and taking out the specimens alive from their normal stations. Species inhabit all kinds of bottom, pebbly, sandy, muddy and gravelly. Some species even prefer narrow crevices in the rocky bottoms of streams, as the *U. punctatus* in the Cumberland River, and *U. fascinans*, in Powell River. The collector who is unwilling, through fear of snakes, colds, or rheumatism, to don an old suit and "wade in," or to strip and dive if necessary, will do well to quit talking about collecting Unionidæ. In many cases they will be found packed so closely in rocky or gravelly bottoms, as to enable one to soon take out bushels of them; they are thus plentiful in the Ohio, Clinch, Holston and Tennessee Rivers.

In such cases a potato-hook, or some implement of the kind, gently crowded in among them, will rake out half a dozen at a pull. The flowing water will wash away the mud and you can select such as you need. These should be carried out on the river-bank, and cleaned before going home; but if this is not practicable, the operation may be deferred until afterward. As in the case of the land shells, wash them clean, and then drop them into a kettle or pan of boiling water. When the shells gape, and the muscles are loosened, scrape out the soft parts, thoroughly wash out the inside of the shell, and again rinse off

the outside. Let the shells stand until all moisture is dried off the outside, and then wrap them close in an old newspaper, to prevent gaping by the contraction of the ligament. Smaller ones may be nested in larger ones on long journeys, where space is desirable and must be economized. But never do so if you can avoid it. It frequently occurs that the shells of Unionidæ, Strepomatidæ, and Limnæidæ are stained with ferruginous and other matters that no amount of washing will remove. If such shells are immersed for a few moments in the oxalic acid solution, these stains will readily wash off, and a judicious use of the acid does not harm the shell in the least. If it is desirable to remove these stains from the Unionidæ, they should be dropped into the acid immediately after washing and before scalding out the animal, the presence of which prevents the acid from coming in contact with the nacre of the shell, which it will slightly dim if the shell remains in it for too long a time. It is often the case among the southern shells that these stains have so obscured the really characteristic markings of the shells as to have made it one of the chief causes of so much synonymy. If dead shells must be taken or muskrat shell-heaps explored, which is sometimes the case, a judicious use of the acetic acid will remove stains, and in many cases fairly well restore the original appearance of the nacre.

The black and dirty univalves which are so generally received in exchange, and also dirty Unionidæ, may be perfectly cleaned by a judicious use of these acids. But while they are to the careful student collector an inestimable boon, a careless or injudicious use of them will ruin every shell so treated.

Where the Strepomatidæ are collected in alcohol or any preservative solution in quantity, they may be subjected to the cleaning process whenever opportunity offers. It will generally only be necessary to immerse those having the worst stains in the acid for a few moments, and then wash and rinse them thoroughly.

In operculated species, the operculum, detached from the animal by a sharp knife, should be carefully preserved. A little cotton can be inserted into the aperture and upon this, the operculum, in its natural position, may be fixed with mucilage.

Many Uniones and univalves are much improved and given the appearance they have when in water, or when wet by rubbing them with a clean sponge, on which are a few drops of boiled linseed oil. "Woolly" shells or those with a soft epidermis may be excluded from this list.

Many of the Unionidæ also have a very highly polished epidermis, and when clean look as well dry as wet. The use of oil is a great improvement to some species, and it preserves all fresh-water shells; but it must be kept off of land species. The Anodontas and thin-shelled Unios sometimes crack when dry. This difficulty may be avoided by dipping fresh specimens into

a solution of chloride of calcium—a hygrometric salt that always retains enough moisture to remain in solution under ordinary conditions of atmosphere and temperature.

Physa, Limnæa and Planorbis must be scalded and the animals removed with the land-shell hooks, and they should afterwards be treated in the same way. If stained treat them with oxalic acid, using it judiciously, and you can clean the worst of them perfectly. Amnicola, Bythinella, Gillia, Somatogyrus, etc., small univalves almost universally stained, should be put into the test tube with the sand and a small amount of the oxalic solution, and shaken as before described for the small land shells. They can thus be rendered perfectly clean and all stains will be removed. You should not undertake to remove the animals from these small shells, as if collected in alcohol as before described, the animals will be much shrunken, and when dried will not disfigure the shell particularly. Sometimes, as in *Physa hypnorum*, the soft parts adhere rather persistently within the apical whorls. In such cases, after the shells have been scalded, take up each specimen singly with the pliers and hold the apex a few seconds against the blaze of a lamp or candle. Soon a small quantity of steam forms with a slight explosion that loosens the soft parts perfectly; a jet of water from the syringe will then remove the soft parts and rinse the shell at one operation.

Pisidium and all the smaller Sphærium are often stained, and should be put in the test tube and treated in precisely the same way. The larger species may be scalded, and the animal removed as above described for the Uniones.

In conclusion, I wish to impress upon all collectors the advantage of having good, clean, perfect specimens of whatever objects of natural history they undertake to study. If the characters are obscured by dirt, or obliterated by decay or erosion, you have no right to complain if those of better tastes in these matters, and of more industry, reject as worthless these evidences of your want of either one or both of these requisites; but if you faithfully follow the suggestions here made, there will be no complaint that you lack either.

The above remarks are intended to facilitate the work of collectors legitimately employed in the advancement of science. Wanton destruction of life will always be deprecated by the naturalist as by the moralist. Do not collect for the fun of collecting; have a purpose, and when that purpose is fulfilled, stop. Take nothing unnecessarily—not even the life of a snail.

In arranging a series of species in his cabinet the collector, if unacquainted with their names, may group his species according to those analogies and obvious resemblances that show their relations to each other. He should attach a label to each species, designating it by a number until he has opportunity to replace

the number by the specific name. The label should have upon it the locality where found, and any other facts that might be of interest to the naturalist. The numbers he attaches to his species may serve as the means of ascertaining names by correspondence. Each species should be marked, so that no confusion may arise by displacement of labels.

Should the collector find it convenient to correspond with some other person similarly engaged, or should he desire to transmit a package of shells to some friend or some public institution, a few suggestions relative to packing shells for transportation may be of use. Obtain a sufficiently strong box of suitable capacity; on the bottom should be laid a thin bed of soft hay, or some other suitable elastic material. The larger shells (if such are to form a part of the contents of the package) should form the lower tiers in packing. Each shell should be wrapped in paper, and the specimens should be so compactly stowed as not to shake about. The lighter shells should occupy the upper portion of the package, and those of a fragile nature should be protected from breakage by being enveloped in cotton and enclosed in suitable small boxes. Small paper bags or cartridges may serve to contain minute species; but a more satisfactory mode is to wrap them in cotton and put them in small paper boxes, such as may be purchased at any drug-store. Each species should be appropriately labeled, giving, in legible characters, the generic and specific name of the shell, if known, after which should be written the name of the author by whom the species was published; under this should follow the locality where found. Any vacant space at the top of the package may be filled with such light material as will serve to keep the contents from shaking about after the box is closed. The top of the box should be carefully nailed secure, and plainly addressed. Packages of light weight are usually forwarded through the mails. It should be borne in mind that in case labels containing names and localities accompany the shells, the package becomes subject to letter postage, but that a very cheap rate is secured if the specimens are accompanied by numbers only. In this case, add to the address on the package "Specimens of Natural History; no writing." The names, designating the numbers by which the specimens are distinguished, will then be included in your letter of advice to your correspondent.

Terrestrial species may be readily kept alive in fern cases, supplying them with sufficient moisture and succulent food; cabbage or lettuce leaves are generally preferred by the phytophagous species. In this manner, the author of these pages has kept the larger exotic species as well as our own mollusks, sometimes for many months, with full opportunity to observe their habits, including copulation, ovipositing, the growth of the young mollusk, etc.

The great contractibility of pulmoniferous mollusks at the moment of death presents an obstacle to anatomical researches. The real position of the organs becomes difficult to recognize, and sometimes the delicate parts become injured; as the dart, for example, broken and fixed in the liver or in other glands.

On placing these mollusks in a vessel of water, closed and deprived of air, the exterior organs will be developed, as the tentacles and the foot; among others, the jaw becomes protruded; and upon adding a little tobacco the verge is plainly protruded and may be recognized. Limaces confined dry in a morsel of tobacco leaf die very quickly, their jaws and verges extruded.

Clausilias may be treated by covering the aperture of the shell with wax, through which a hole may be pricked, large enough to permit the passage of the animal, but too small to permit its retraction after its tissues have become swollen by water; in this way preparations can be made in which the jaws are thrust out and the tentacles extended.—MÖRCH.

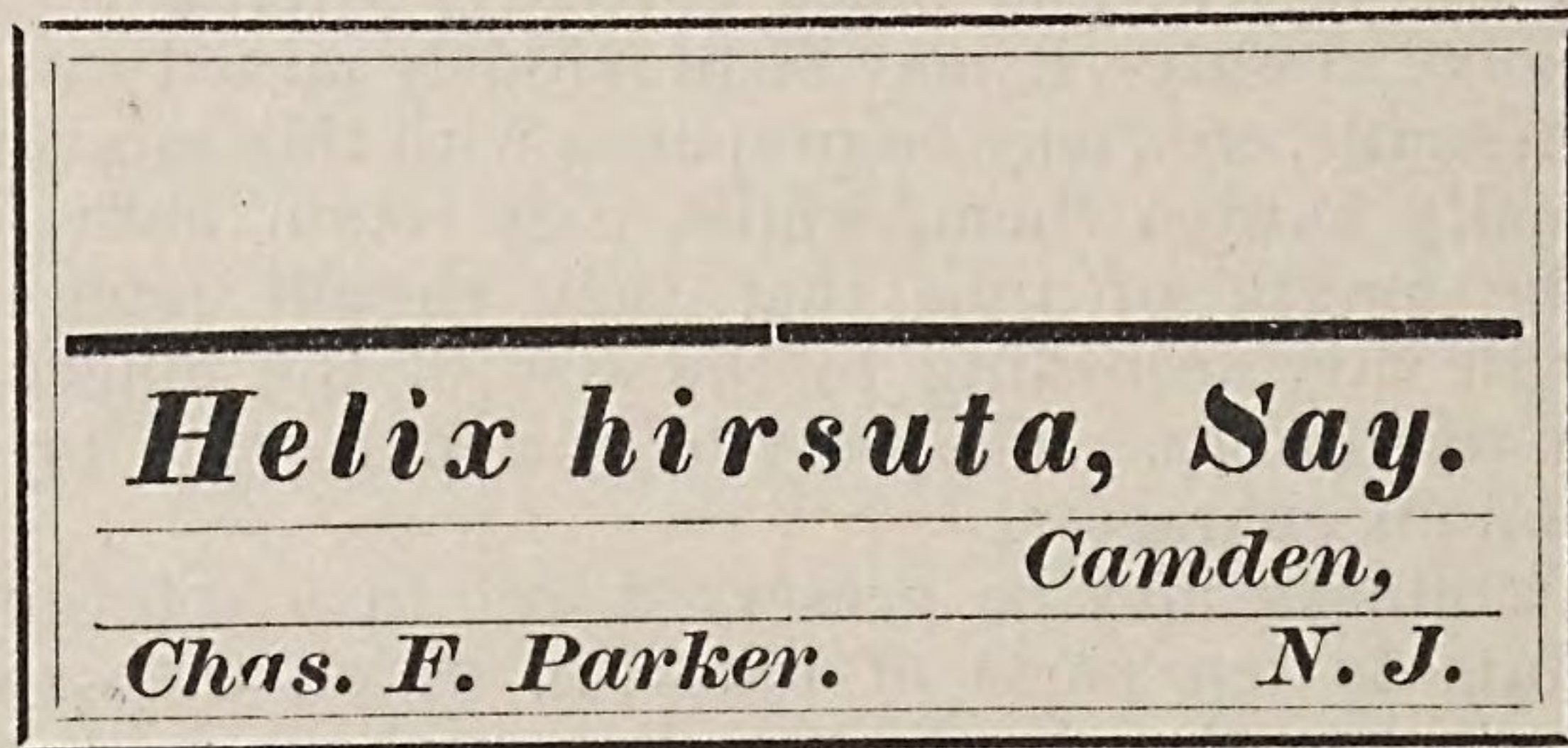
Naked mollusks may be mounted dry by preserving them in a saturated solution of sal ammoniac and corrosive sublimate. To prepare this solution, mix in water ten parts of the former to one of the latter; and since corrosive sublimate does not easily dissolve in water, it may be previously mixed with alcohol. Cuttle-fish, snails, etc., may be prepared with this mixture, which will gradually harden them, whilst they retain both form and color. The length of time that they should remain in the solution will vary according to the size of the object and the density of its tissues. The only objection to this preparation is its poisonous character.

Naked mollusks may be preserved wet in a solution of one part of alum to ten parts of water, in which they will retain their colors better than in alcohol; but no shells must be placed in this solution, on account of its acid property. Sections of spiral shells are prepared by applying the specimen to the side surface of a grindstone; they are useful to show the internal characters; and no better use of duplicates can be made than to prepare at least one longitudinal and one transverse section to illustrate each genus (i, 6, 8, 14; ii, 30; iv, 63).

Shells are usually kept in drawers of convenient size for handling, and about two inches in depth; they are thus compactly disposed and secluded from dust and light—the former injuring their appearance, the latter causing the delicate colors to fade. The few specimens too large to put in drawers may constitute a display-cabinet for exhibition under glass in either a horizontal or upright case. For effectual preservation from dust it is better to close in two rows of drawers with a pair of doors; which may have a lock for security. In the collection of the Academy of Natural Sciences of Philadelphia, the more

showy genera are arranged in horizontal cases, and beneath these are drawers made three inches deep so as to receive a glass sash, which is locked in. By this method the contents of the drawers, equally with those of the cases, may be viewed by visitors to the Museum.

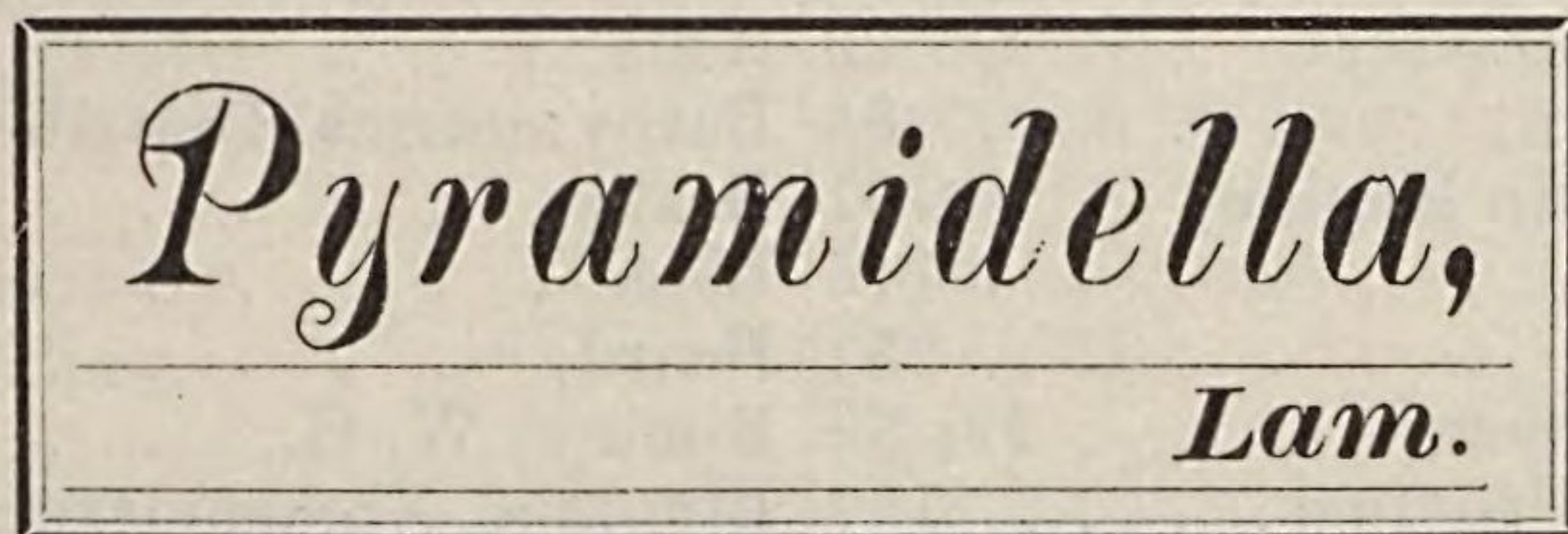
The method of mounting and arranging shells practiced in that institution will, it is believed, be found by amateurs the simplest and best plan for them to pursue. Three inches is adopted as the regular width of the paper trays which contain the specimens and these trays are assorted of the following lengths: 1, $1\frac{1}{2}$, 2, $2\frac{1}{2}$, 3, 4, 6 inches; besides these there are the supplemental sizes 4x6, 6x6, 6x9, 6x12, 9x9, 9x12, 12x12. In these trays are placed blank labels, printed on fine, heavy card-board, made just enough smaller than the trays to fit in them closely. The upper blank space (which alone varies in size, is intended for the specimens, the lines below (as indicated in the sample herewith given) are for the scientific name, locality, and name of collector or person from whom the specimens have been received—all of which should be carefully *printed* with the pen. Patience and practice will be necessary to produce handsome labels.



To these cards the specimens are fixed by any good paste or glue having plenty of body, care being taken that the shell has no oil on the surface—which will prevent adhesion. The label may be scratched, where it is intended to affix the specimen, for the purpose of securing a better adhesion to the paper. A mixture of yellow wax and pitch is an excellent medium and is in use in the institution above named; it has plenty of body and is not attacked by insects, but requires to be melted for use. Liquid glues and pastes are more convenient, but should be poisoned with corrosive sublimate, or the appearance of your cabinet will be ruined by museum pests. Considering the danger of using a poisoned paste, it will be better to procure a glue-pot fixed above an alcohol lamp, and use the wax and pitch mixture.

In mounting a series of specimens choose a label of sufficient size to display them without crowding, and attach them by such parts that when complete the species shall be exhibited in different

positions, so as to show every portion of the surface as well as all variations due to age, size, color, sculpture, etc. A separate label should be used for each locality of a species. When specimens are too small to be mounted on the card-board, they are enclosed in a glass test-tube, made without flange, and two and three-quarters inches in length; so that a cork may project from the open end sufficiently to secure a *bite* against the walls of the tray and thus prevent the tube from rolling. The smallest sized tray mentioned above is not intended for specimens: it is placed bottom-up in the collection, and to it is affixed a label like the following, containing the name of the family, subfamily, genus, subgenus or section.



A similar label, printed on thin paper is used for specimens in alcohol, and is pasted on the upper part or neck of the bottle. The best quality of bottles with ground-glass stoppers are used to prevent the waste of alcohol by evaporation. Alcoholic specimens are best displayed in an upright case.

To return to the dried specimens: fossils, or those of light color will appear much better if care is taken to paste a dark-colored or black paper upon the label before affixing the shells. The genera are separated in the drawers by thin wooden strips, made of walnut and oiled or varnished, or of light-wood and painted. These strips made to fit tightly, also serve to hold the trays in place in case these do not fill a drawer. Each drawer should bear a label upon its face designating its contents—the section, genus or family, as the case may be.

Very common specimens, if carefully cleaned and mounted and labeled will be found quite attractive, whilst the most showy species will, on the other hand, lose nearly all interest if carelessly prepared. The best collectors value their cabinets for their *condition* quite as much as for their *contents*: and legitimately so, for whilst carefully preparing his specimens the collector learns their characters, and when so prepared they are disposed so as to reveal these characters to others.*

* For the convenience of those residing away from the larger cities, where only museum supplies may be obtained, I annex the names of the persons who furnish similar articles to the Philadelphia Academy:

Paper trays: Union Paper Box Co., Cor. 5th and Jayne Streets; Card-board labels: W. P. Kildare, Printer, 736 Sansom Street; Glass tubes: John A. Yunk, 1126 Market Street. (All of Philadelphia.)

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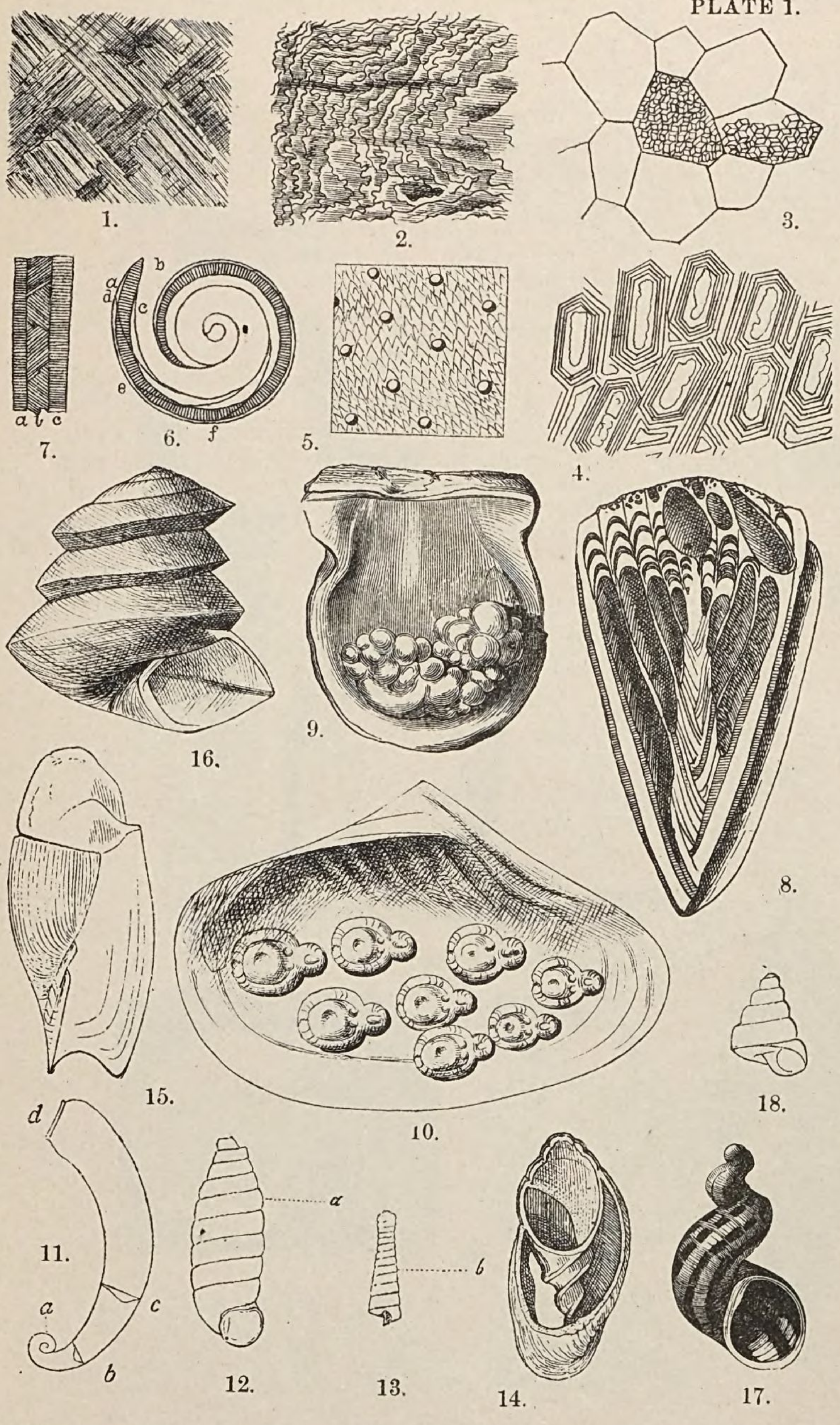
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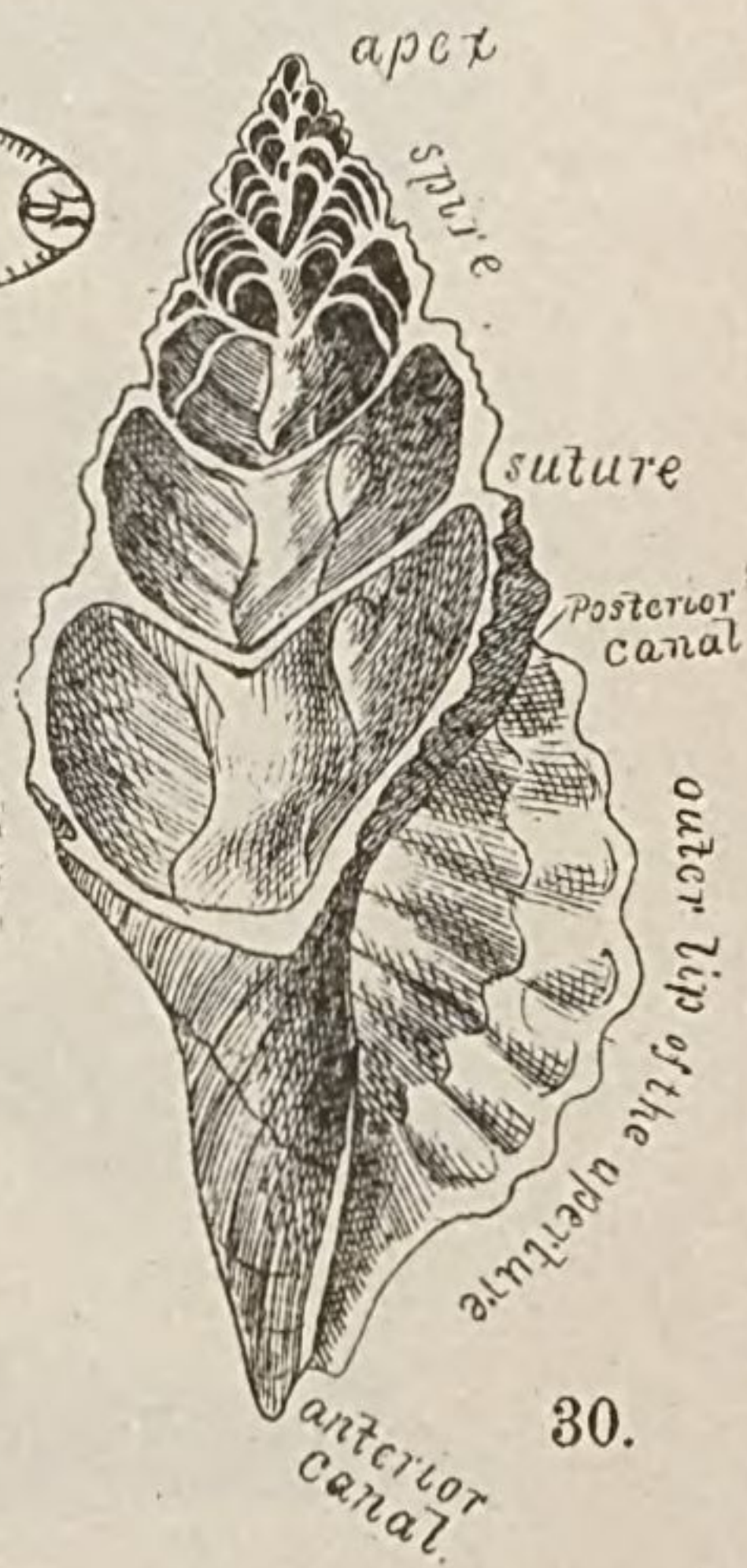
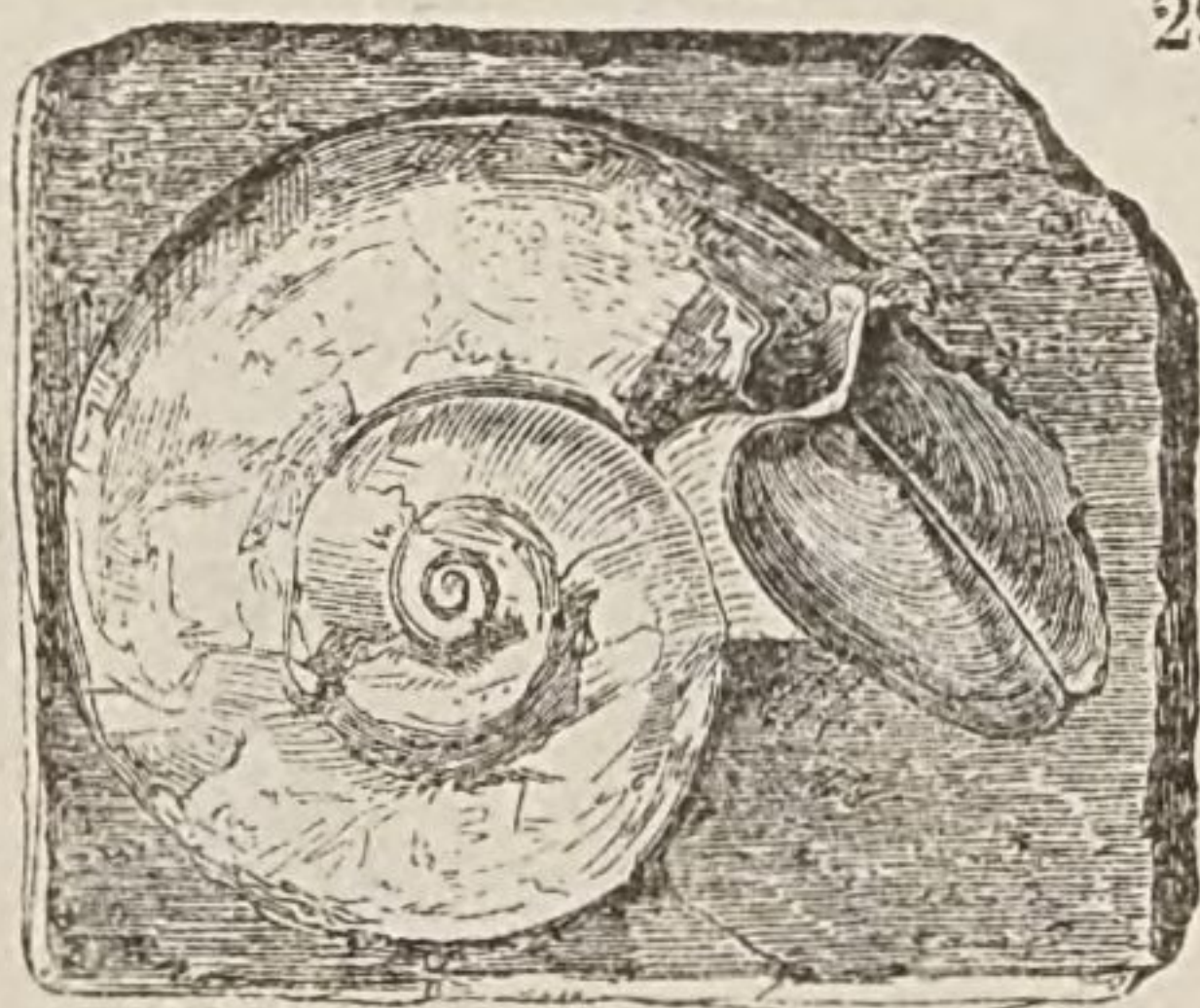
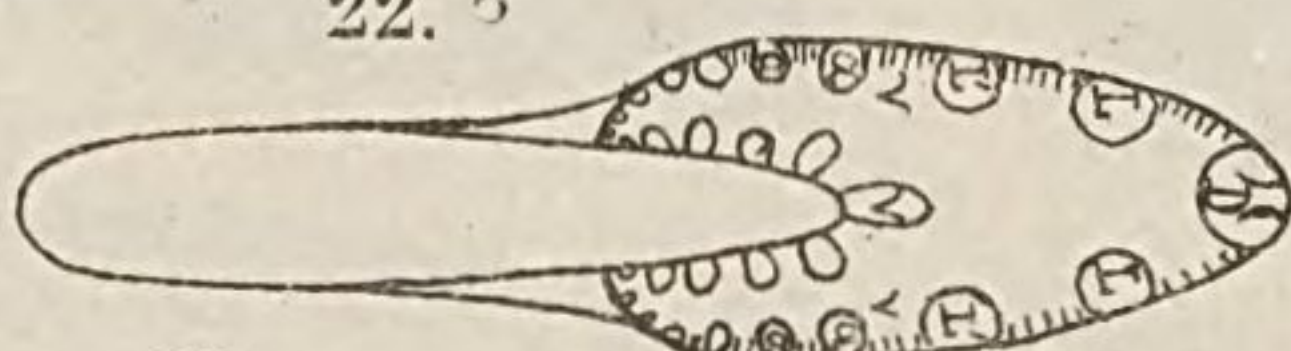
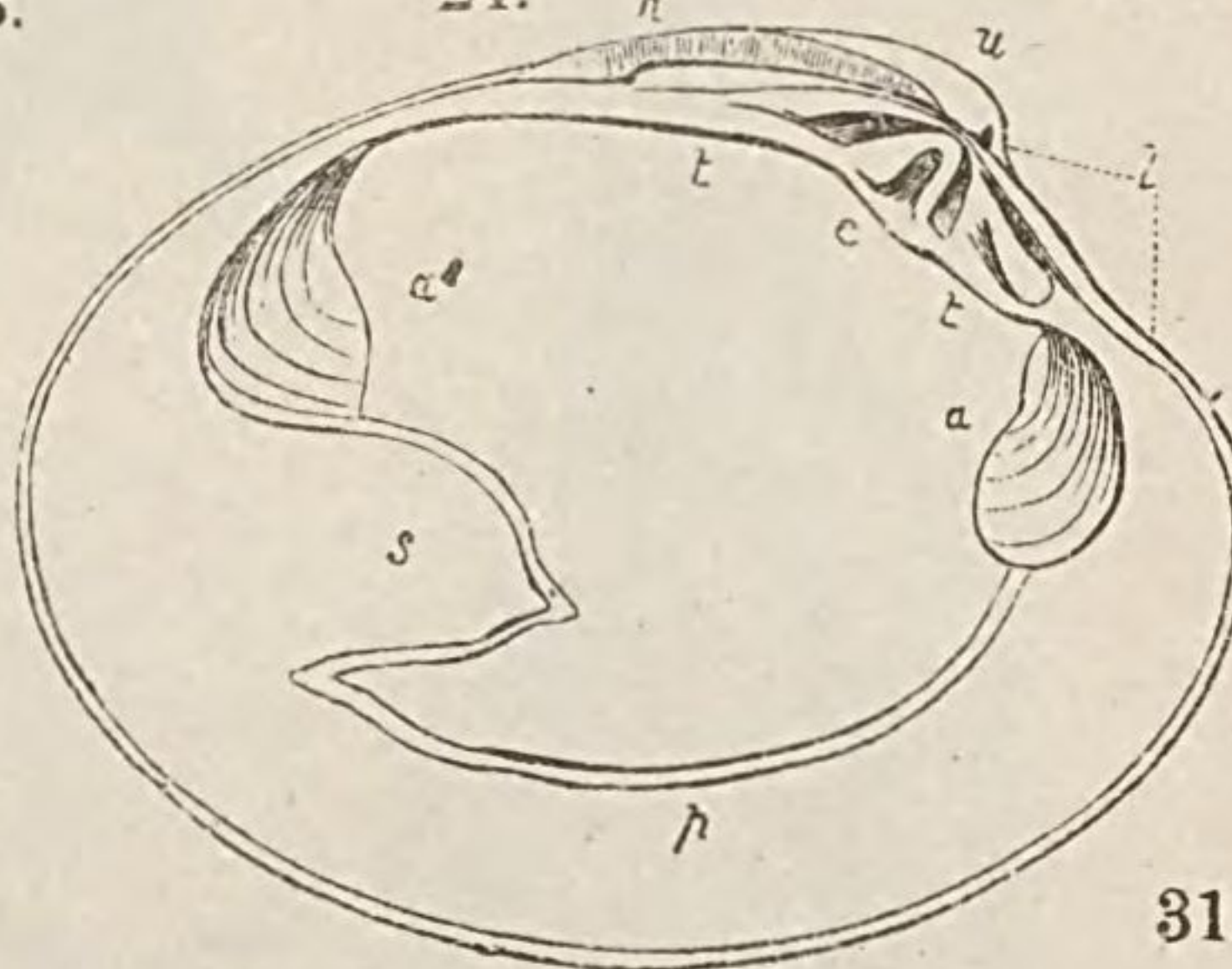
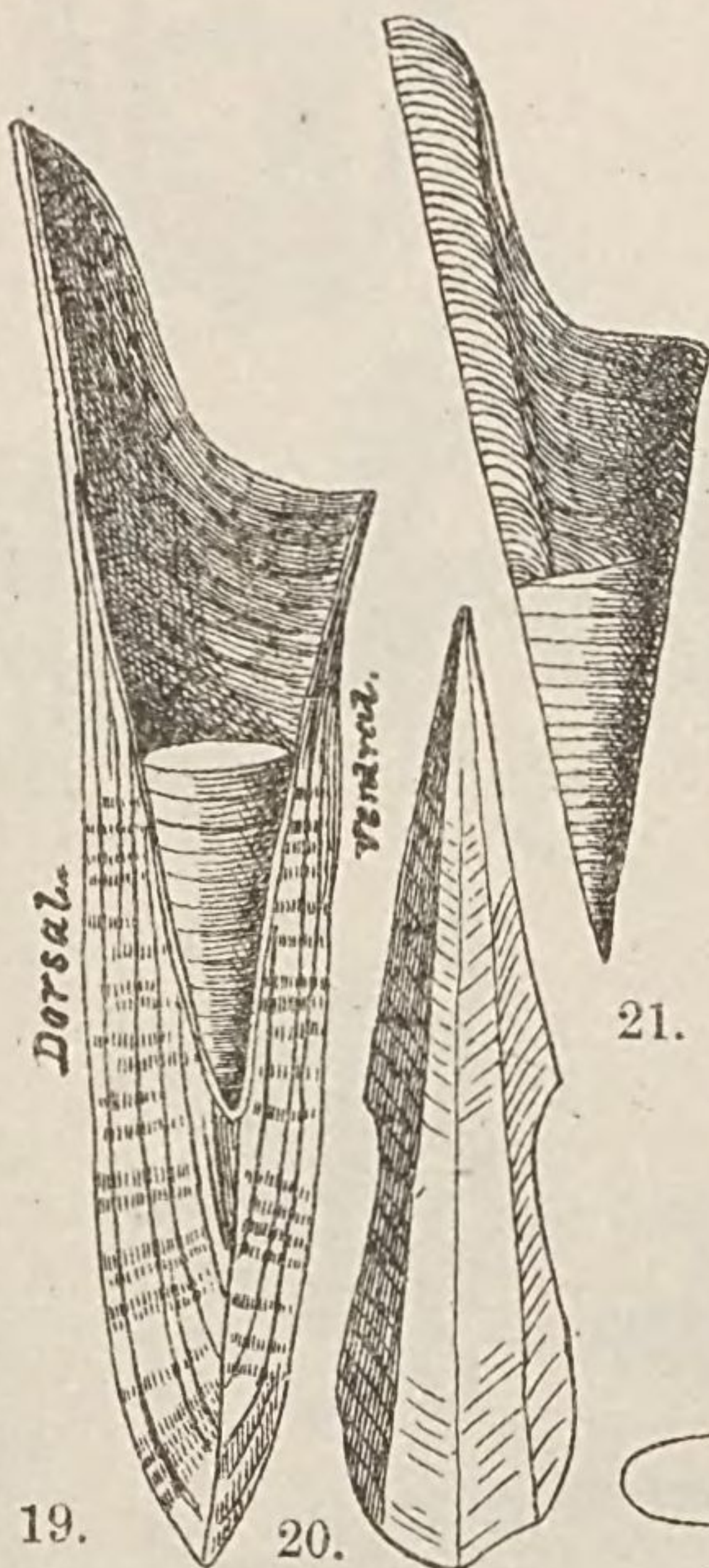
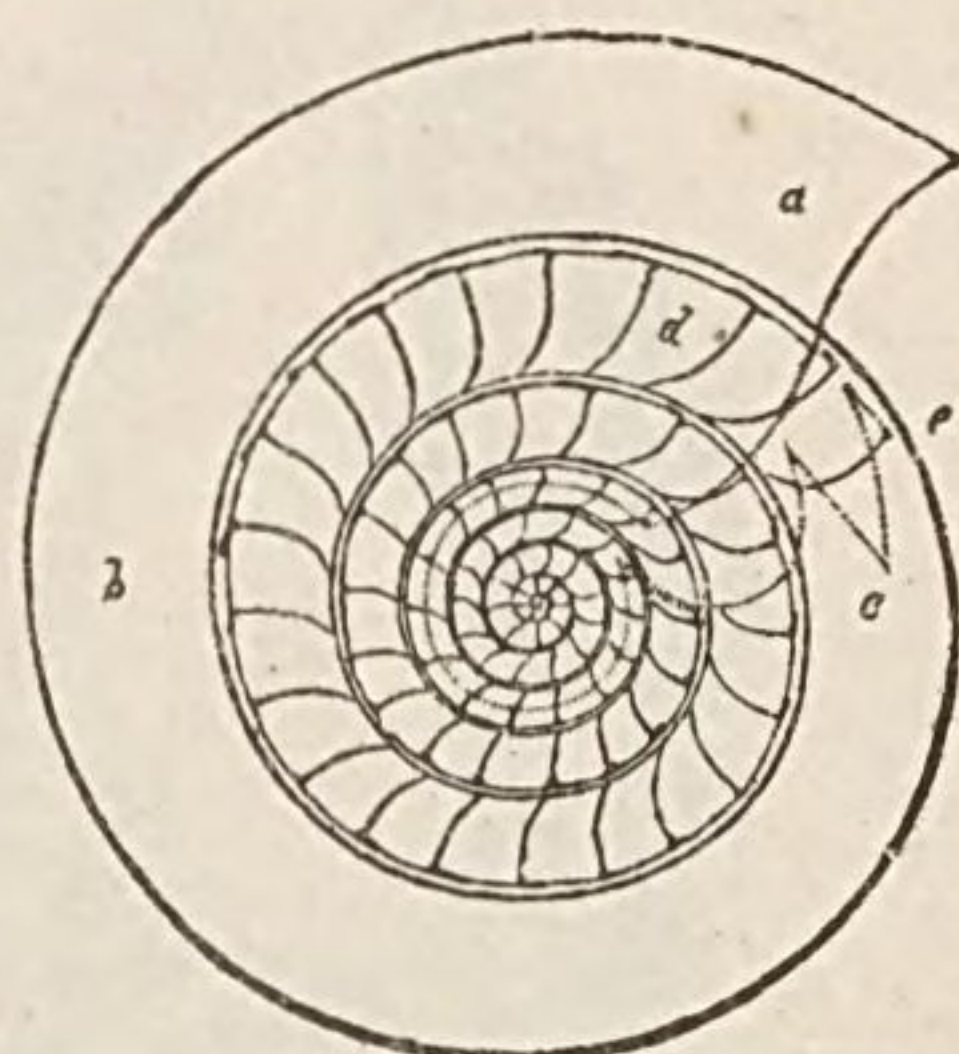
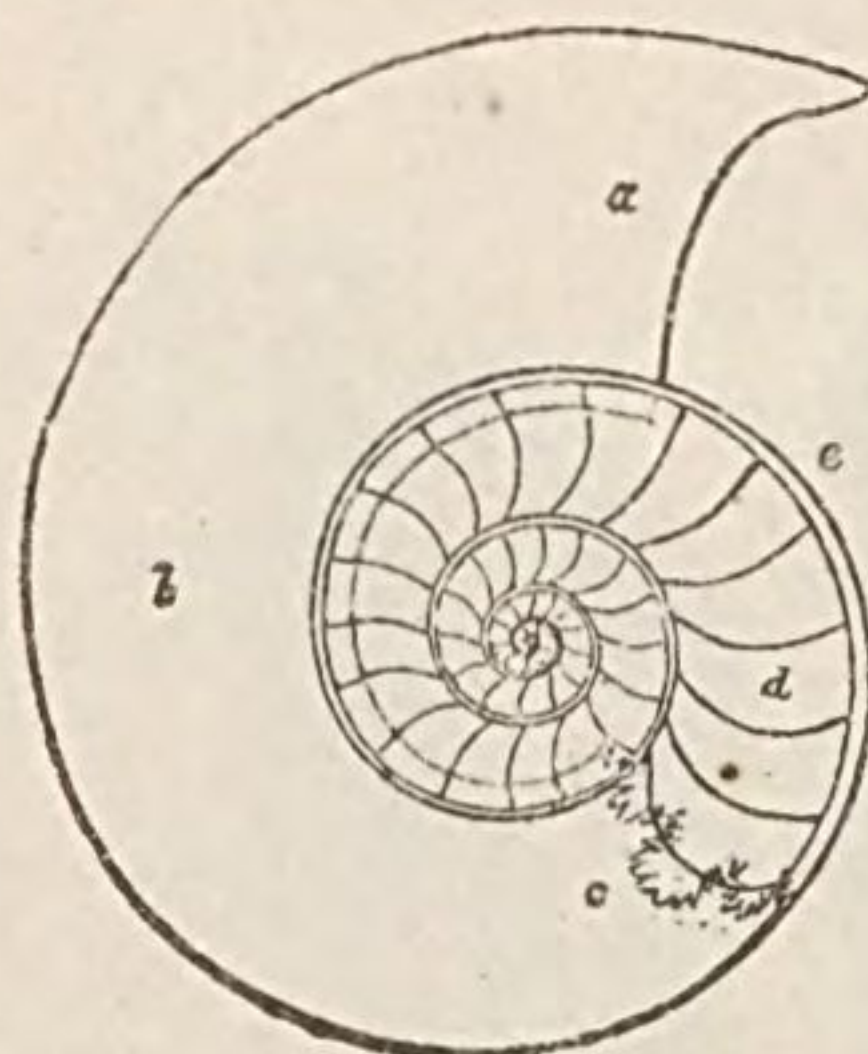
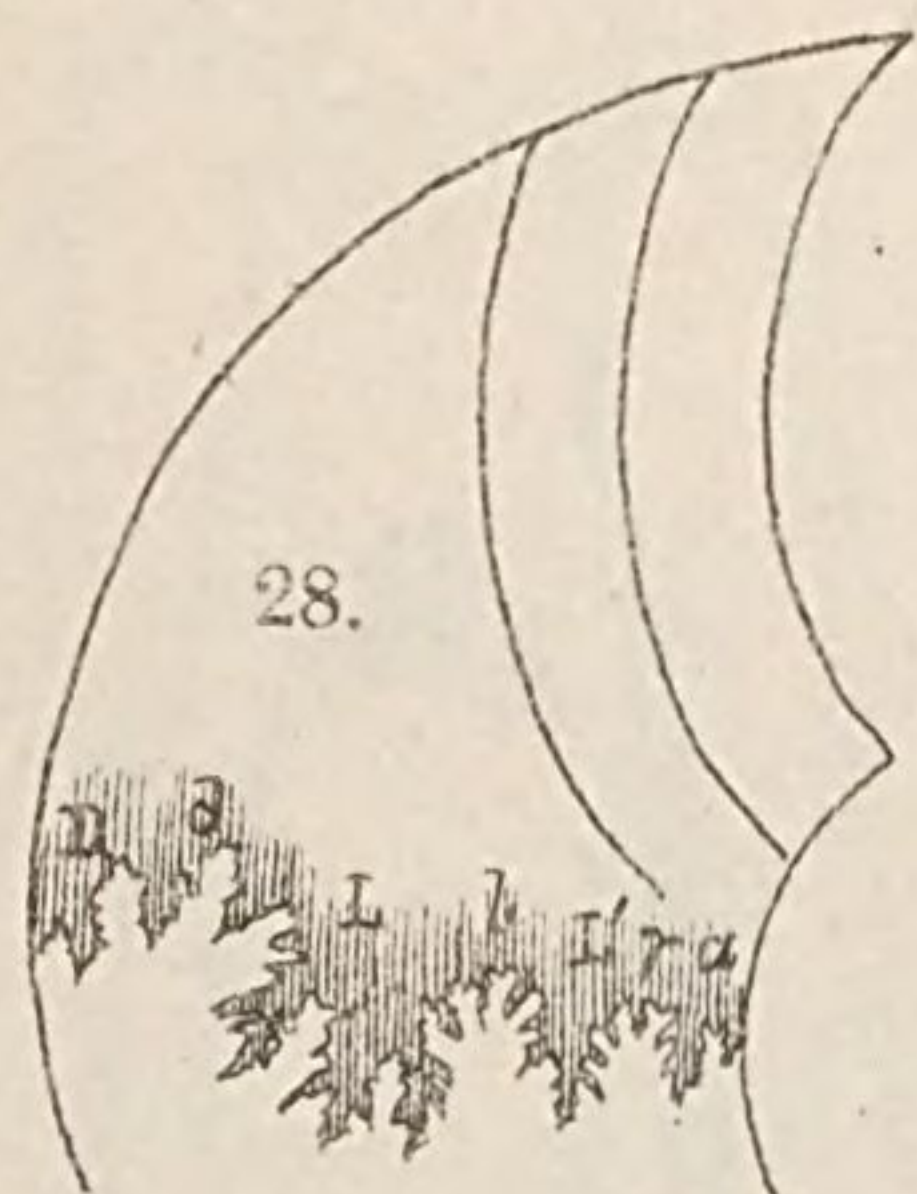
PLATE 22.

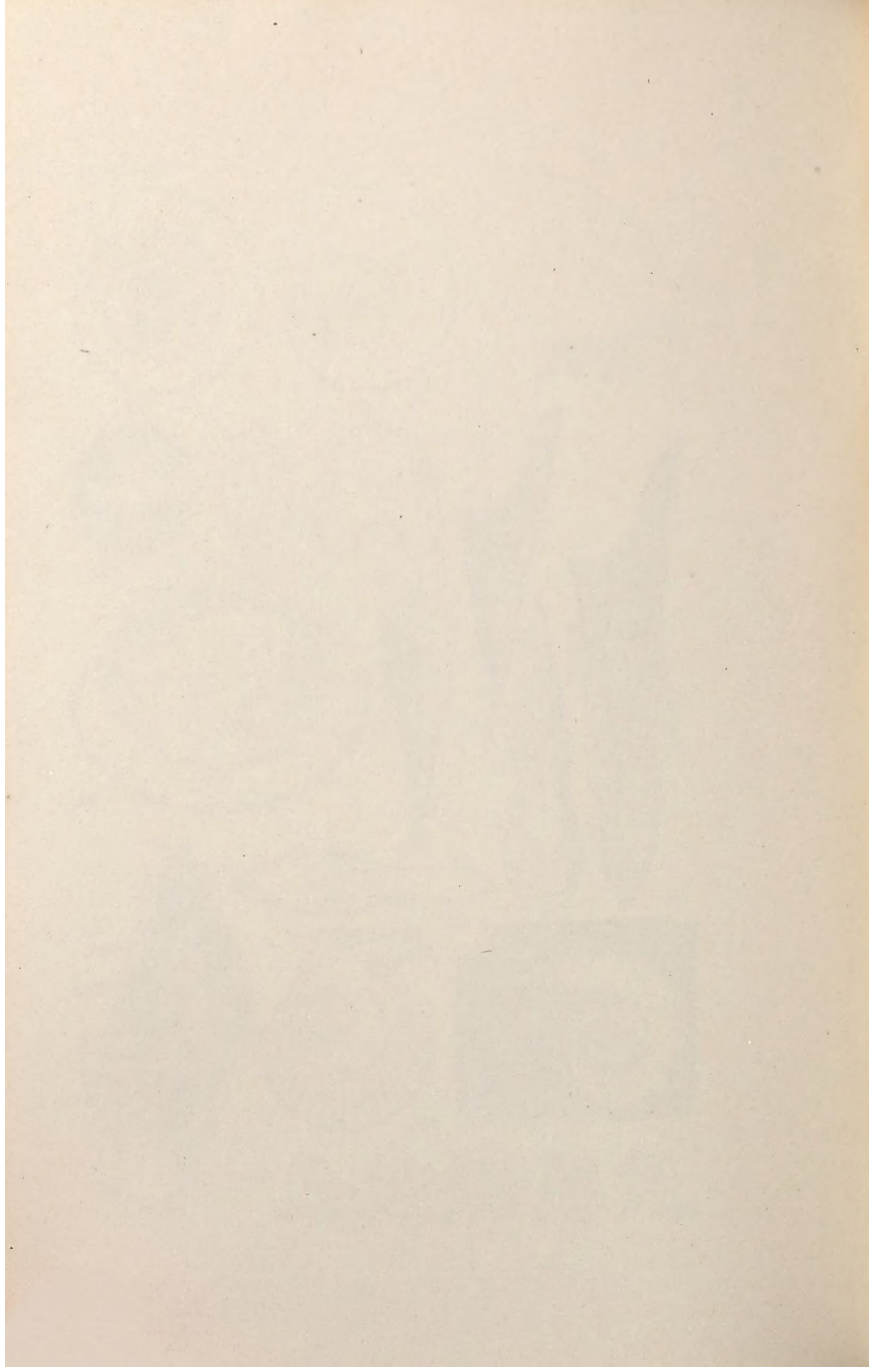
64. Generative organs of the American oyster. *P*, labial palpi; *H*, heart; *Mus*, adductor muscle; *Mt*, mantle; *G*, branchiæ; *Gen*, generative organs; *ov*, oviduct. (Ryder), 124
65. Anatomy of the American oyster. *H*, hinge; *lig*, ligament; *A*, lower margin of shell; *G*, gills; *Cl*, cloaca; *V*, vent; *Mus*, adductor muscle; *I*, *II*, *III*, its areas; *b* to *c*, upper side of the animal; *c* to *a*, lower side; *Mt*, mantle; *tent*, tentacles; *P*, palpi; *P, sp*, palpal space; *I, cav*, gill cavity; *e*, gill membrane; *mes*, mesosoma, or lower middle portion of the body; *Uc*, upper gill cavity; *M*, mouth; *st*, stomach; *æ*, œsophagus; *L*, liver; *Cst*, crystalline stylet; *Int*, intestine; *Per*, pericardium; *I, fads*, double fold of intestinal cavity; *ve*, ventricle; *au*, auricle; *a o*, *a o'*, aortæ; *bc*, branchio-cardiac vessels. (Ryder), 86, 105

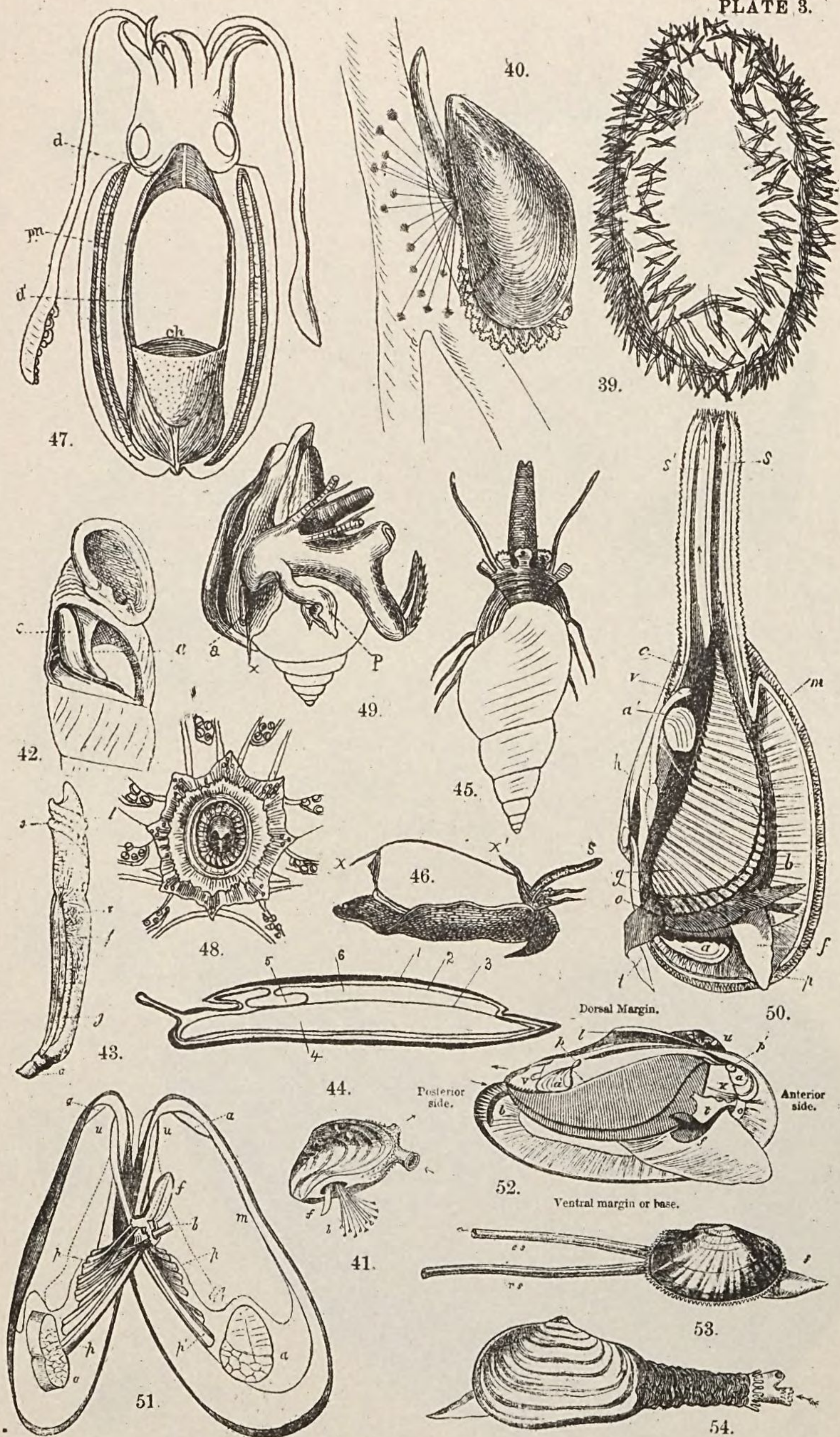


PLATE 1.







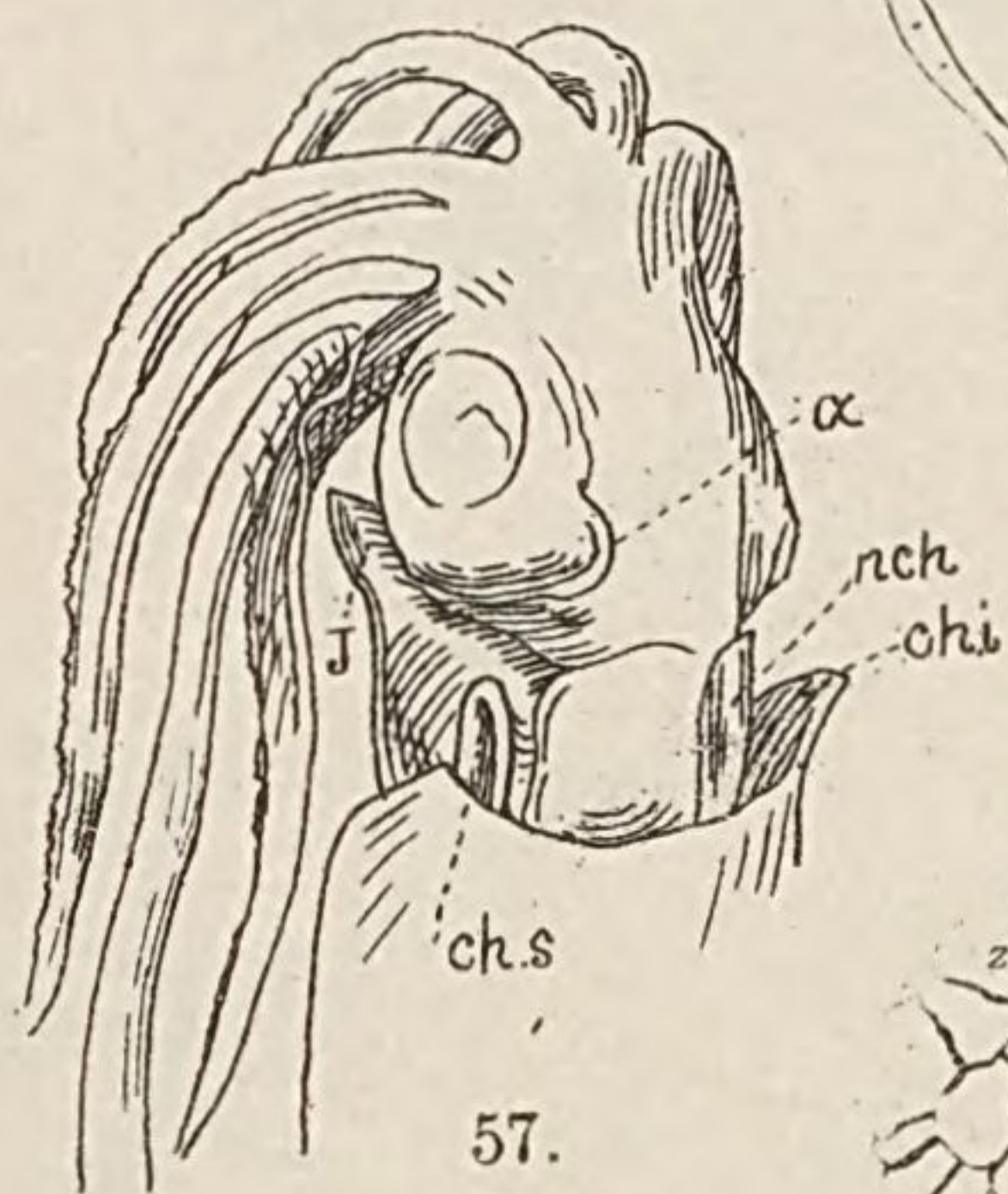




55.



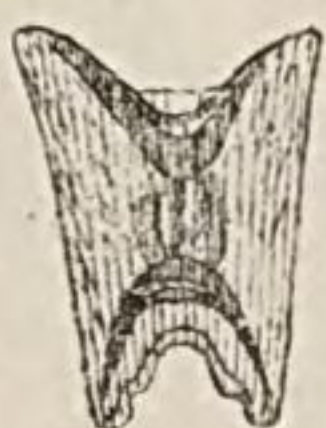
56.



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59.



58.



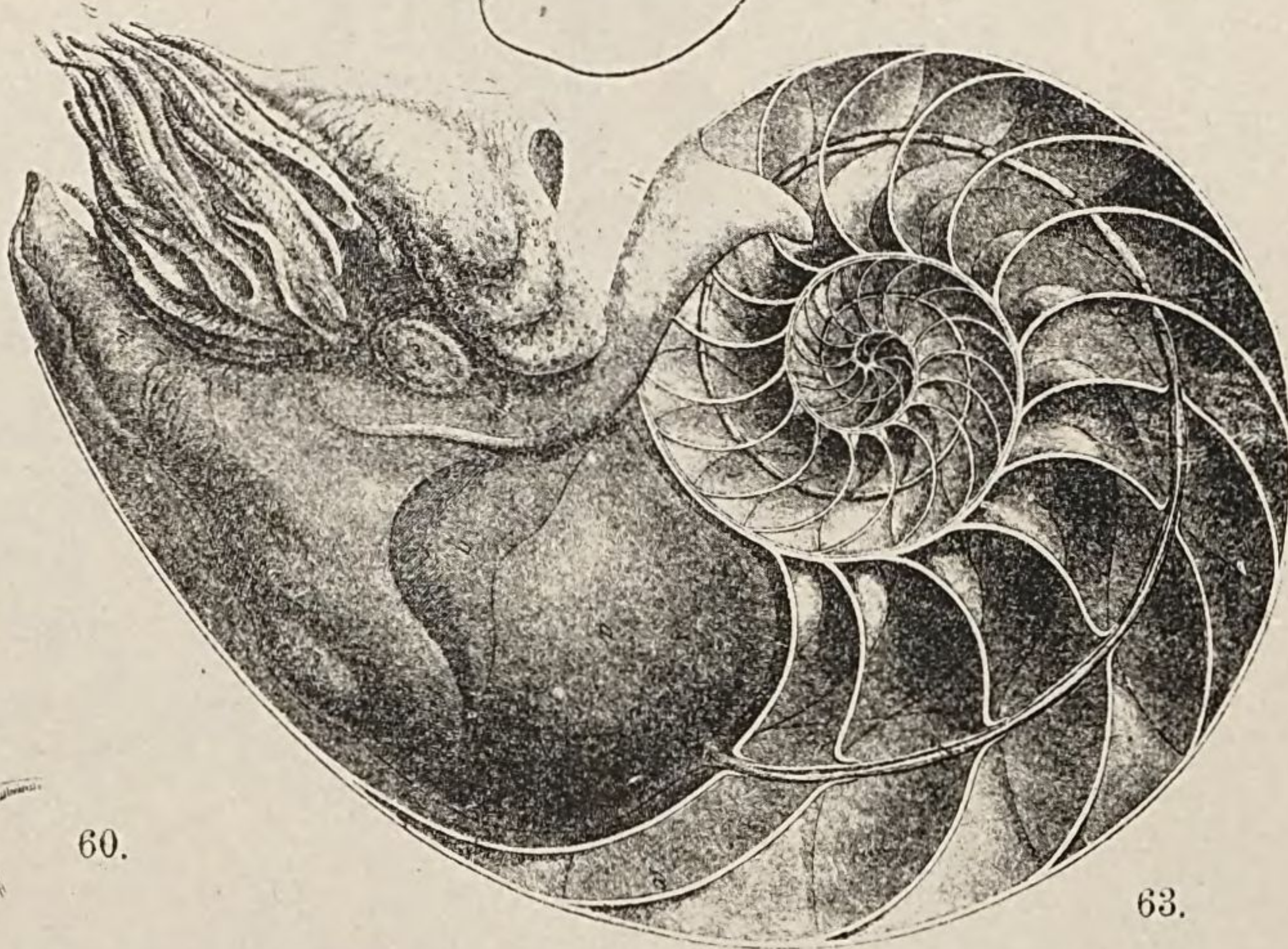
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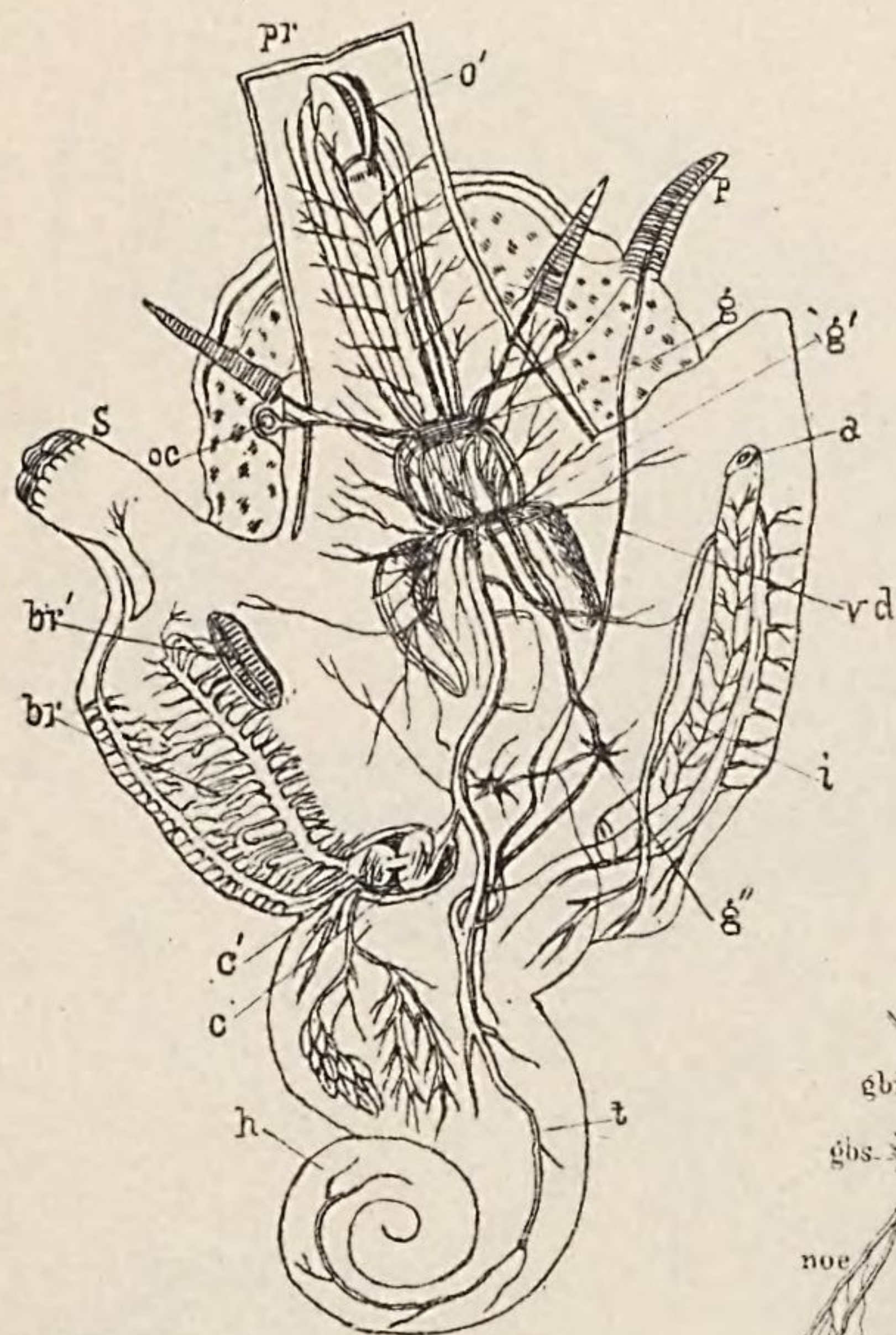
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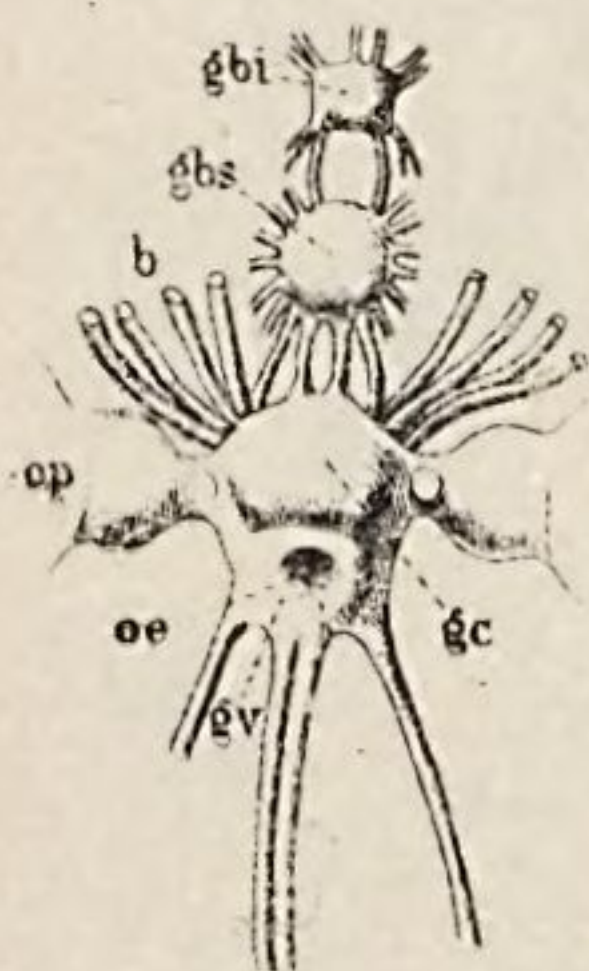
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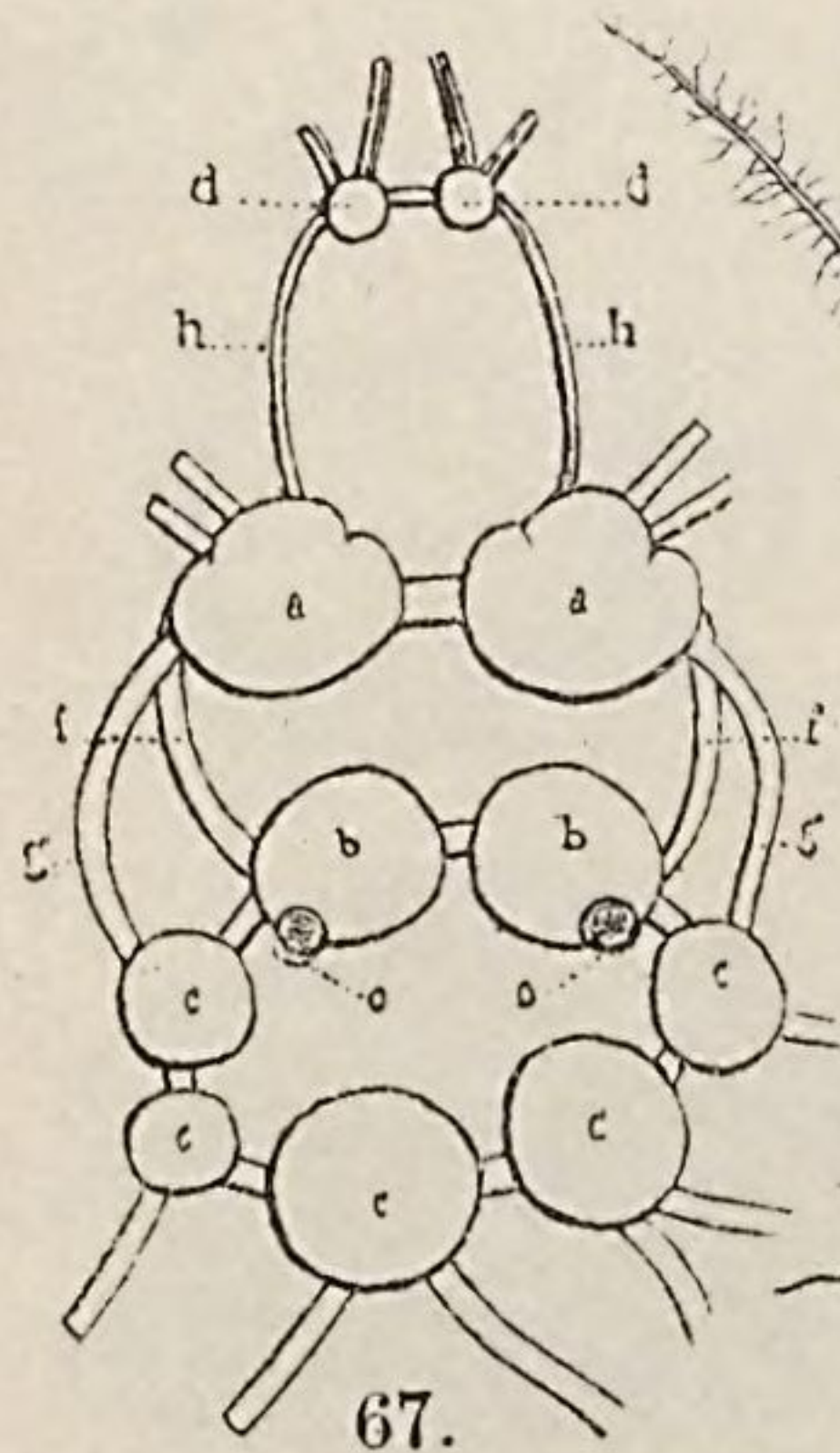
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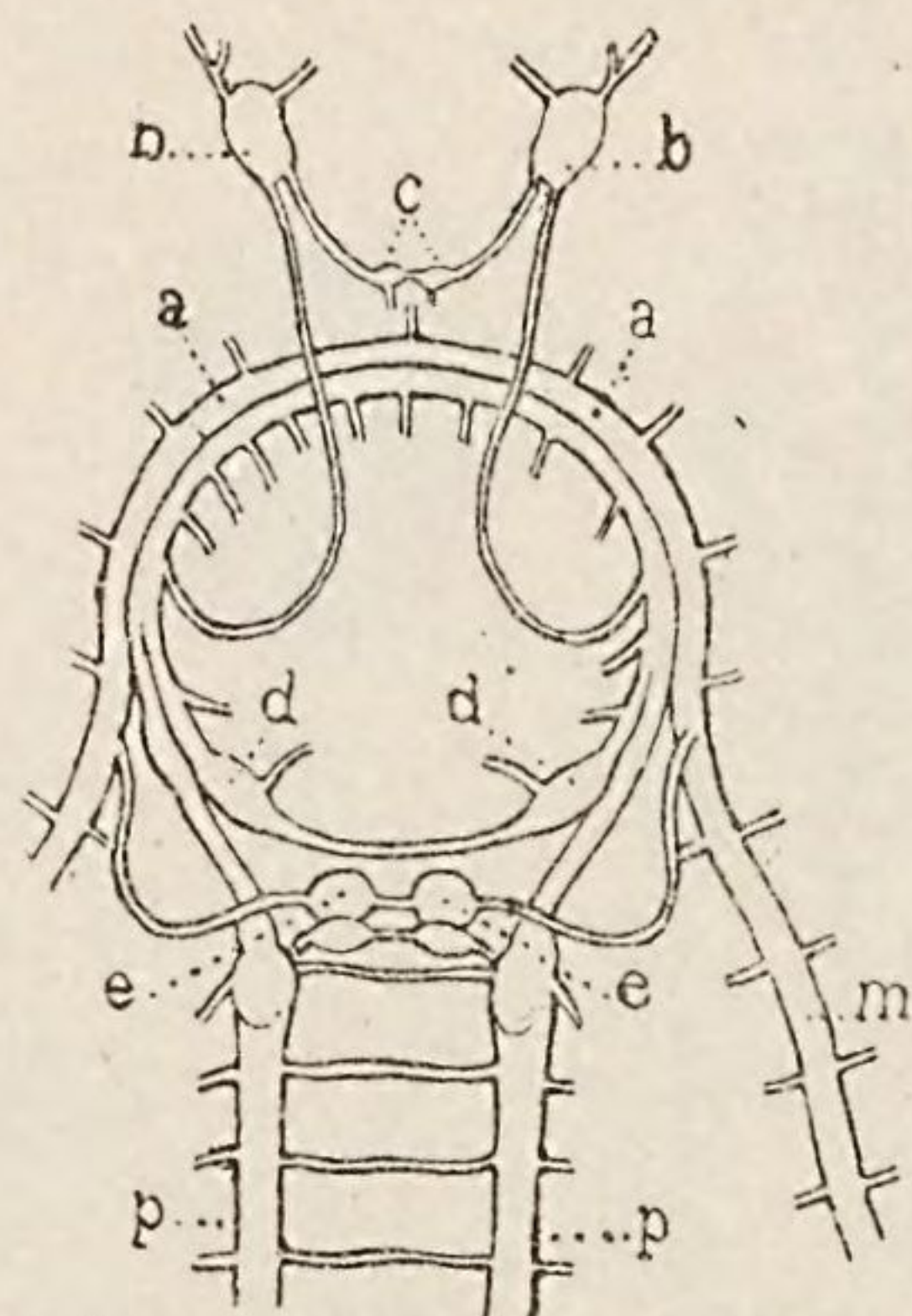
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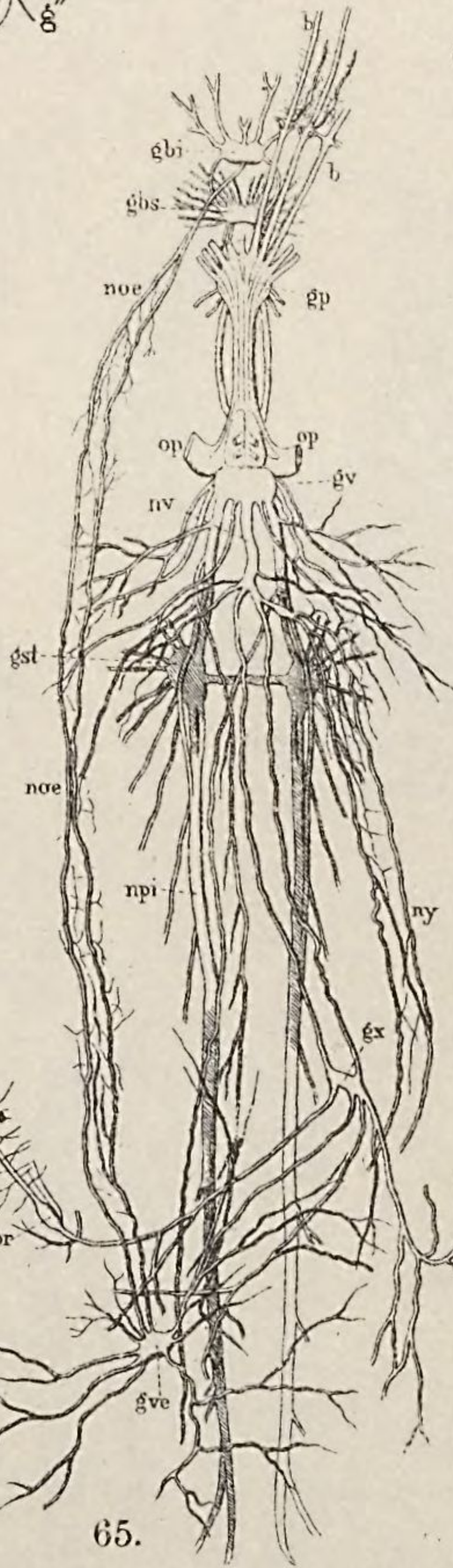
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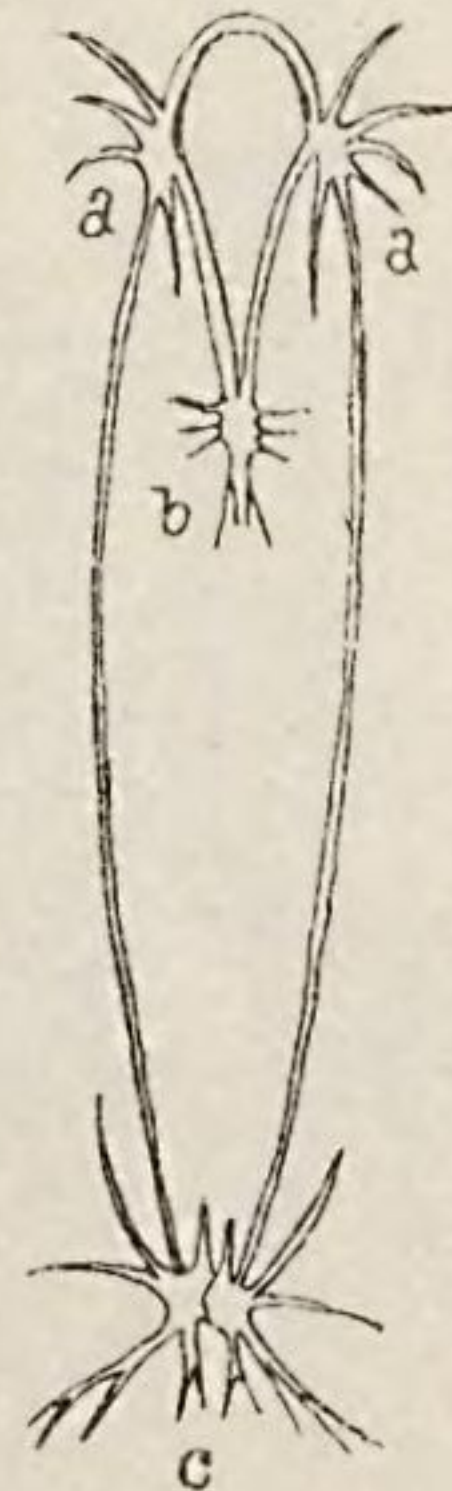
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68.



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PLATE 6.

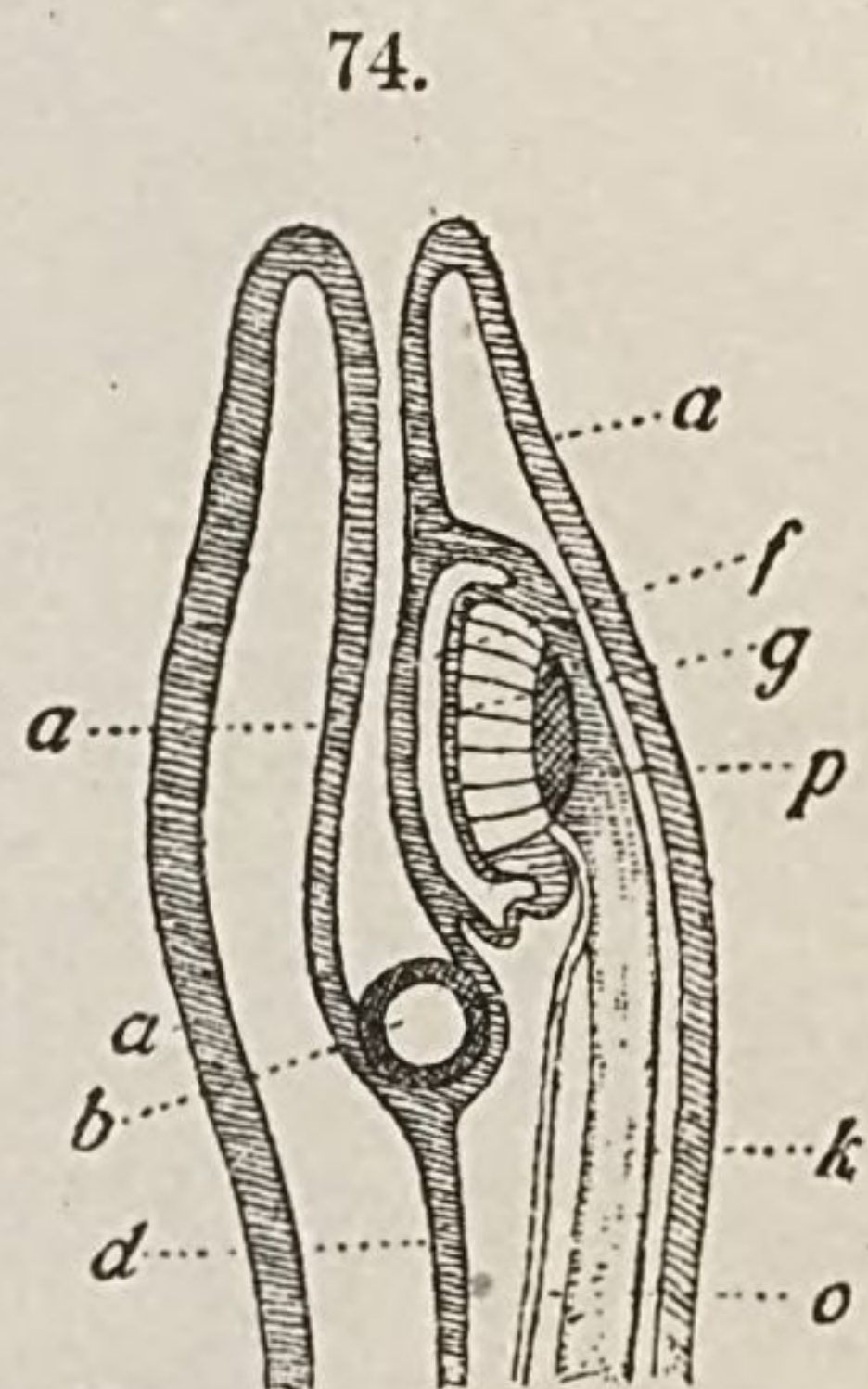
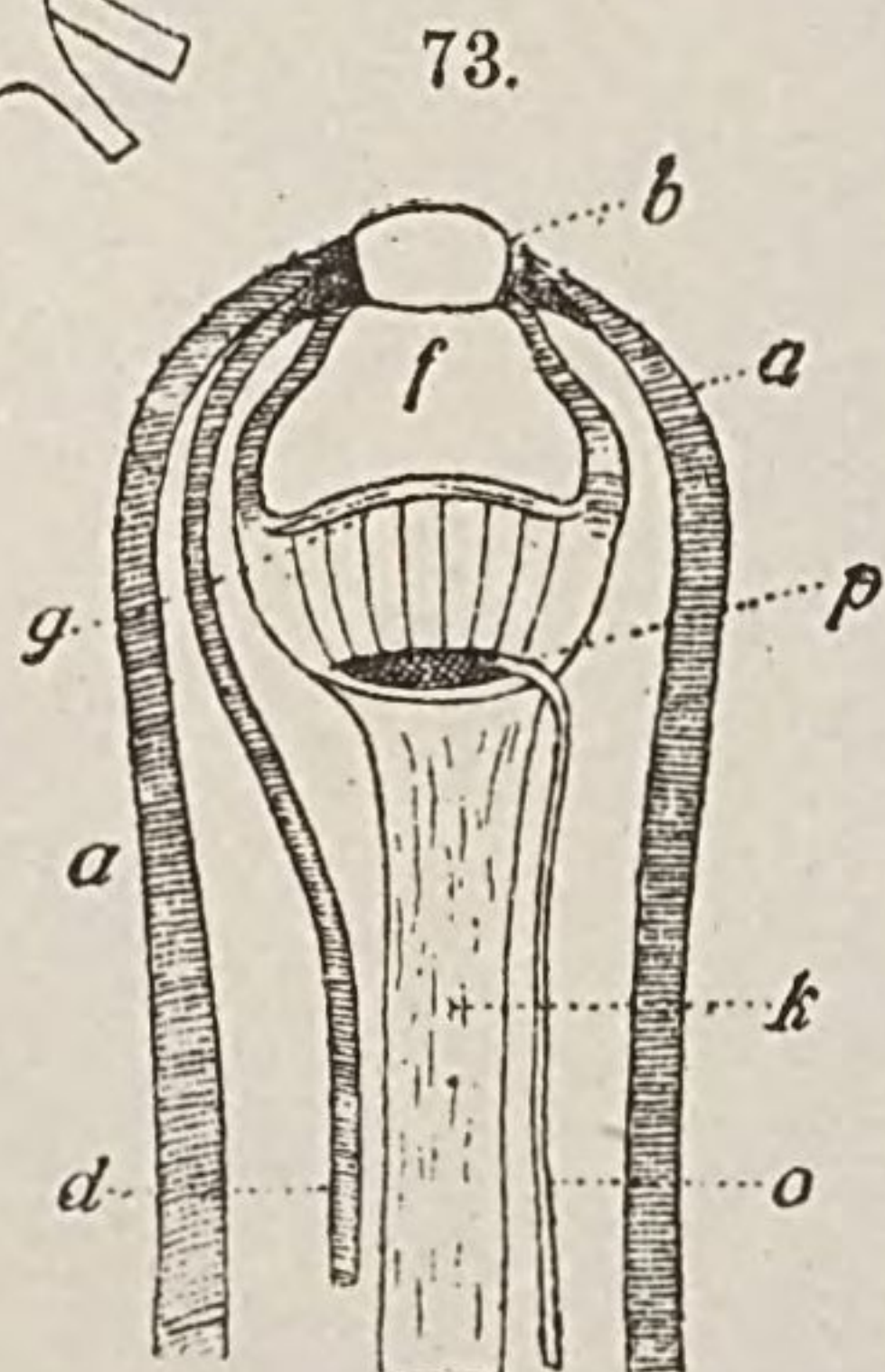
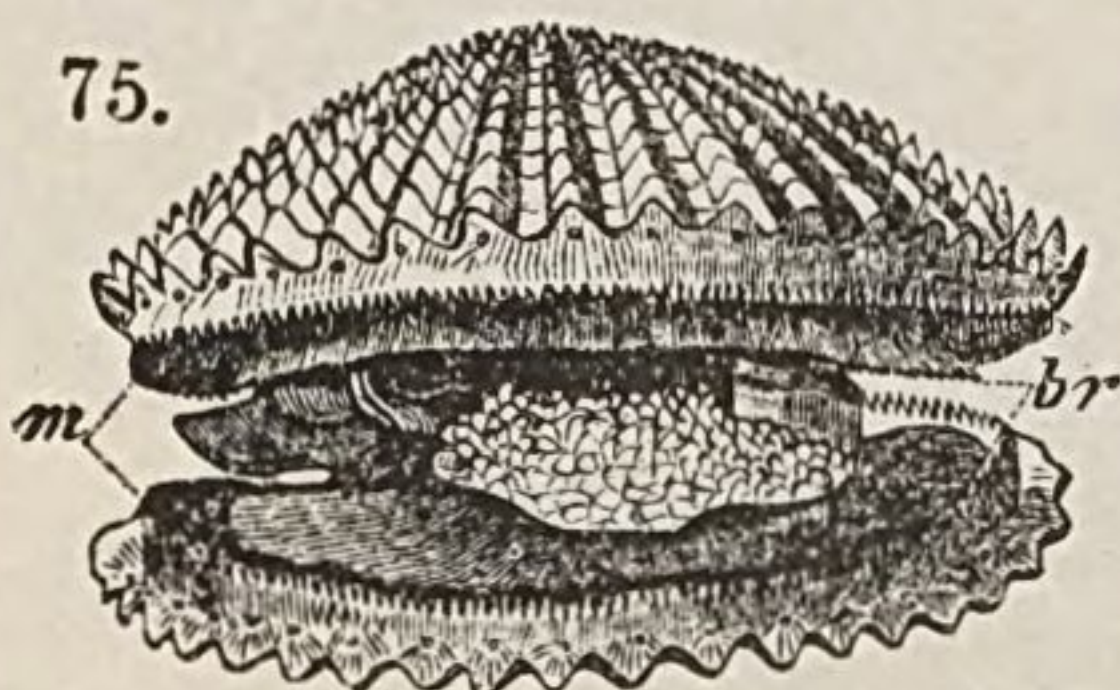
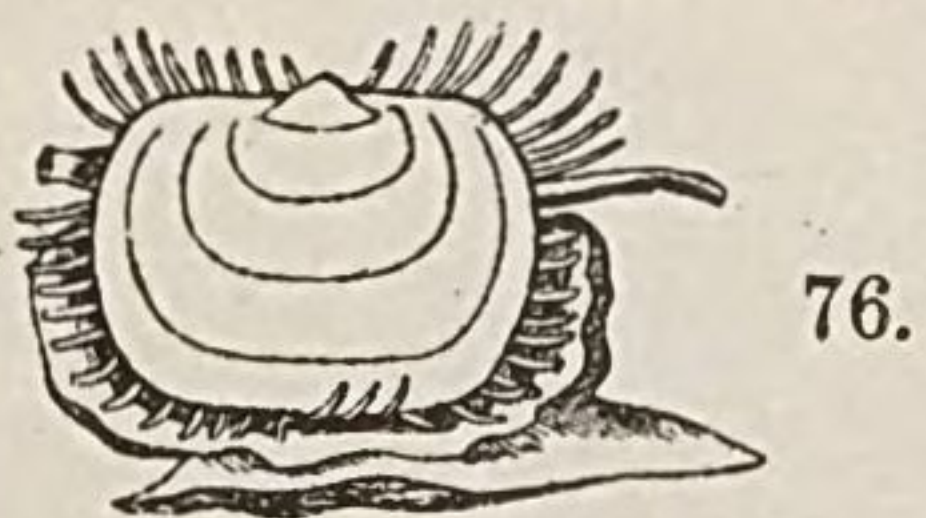
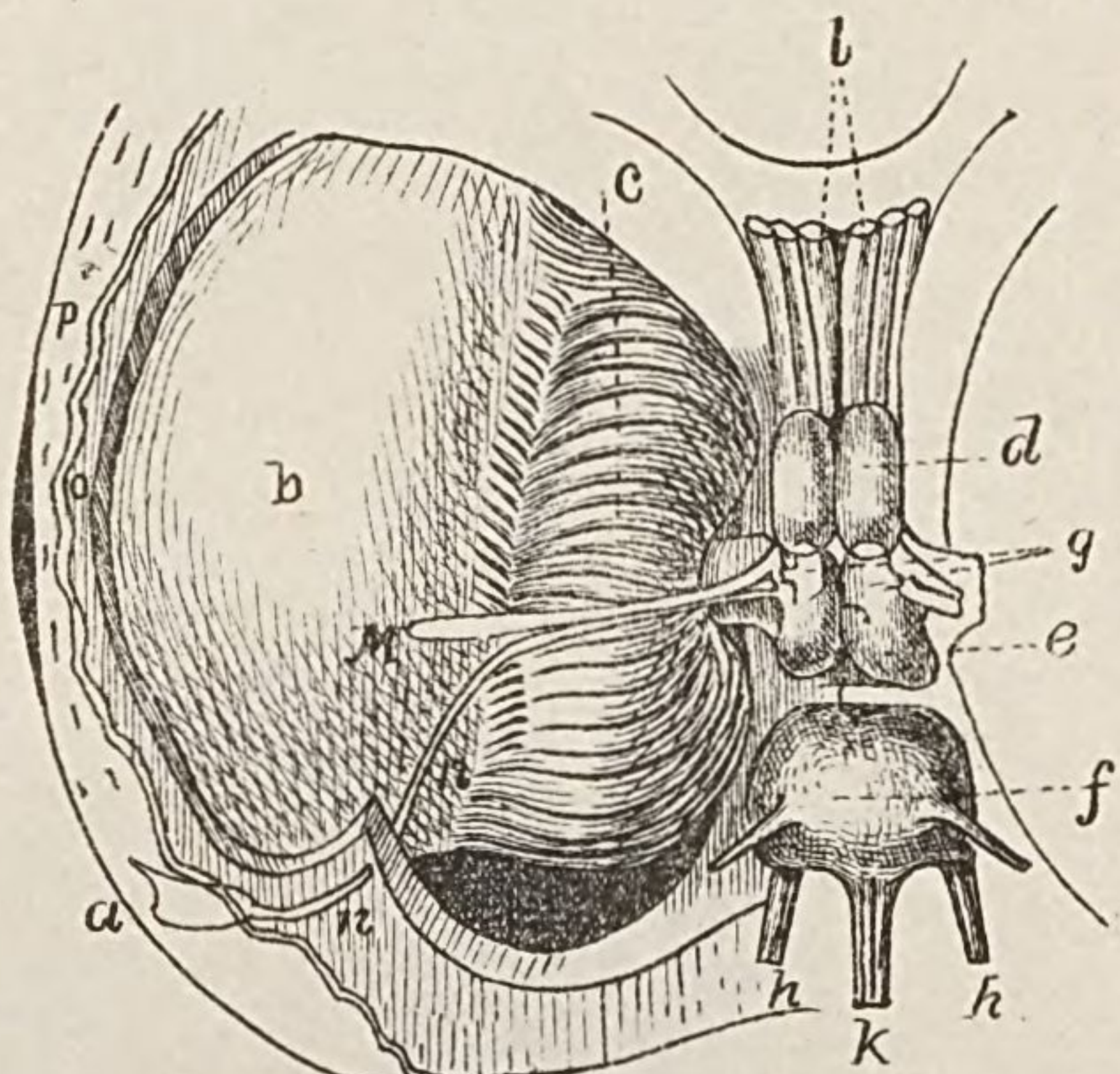
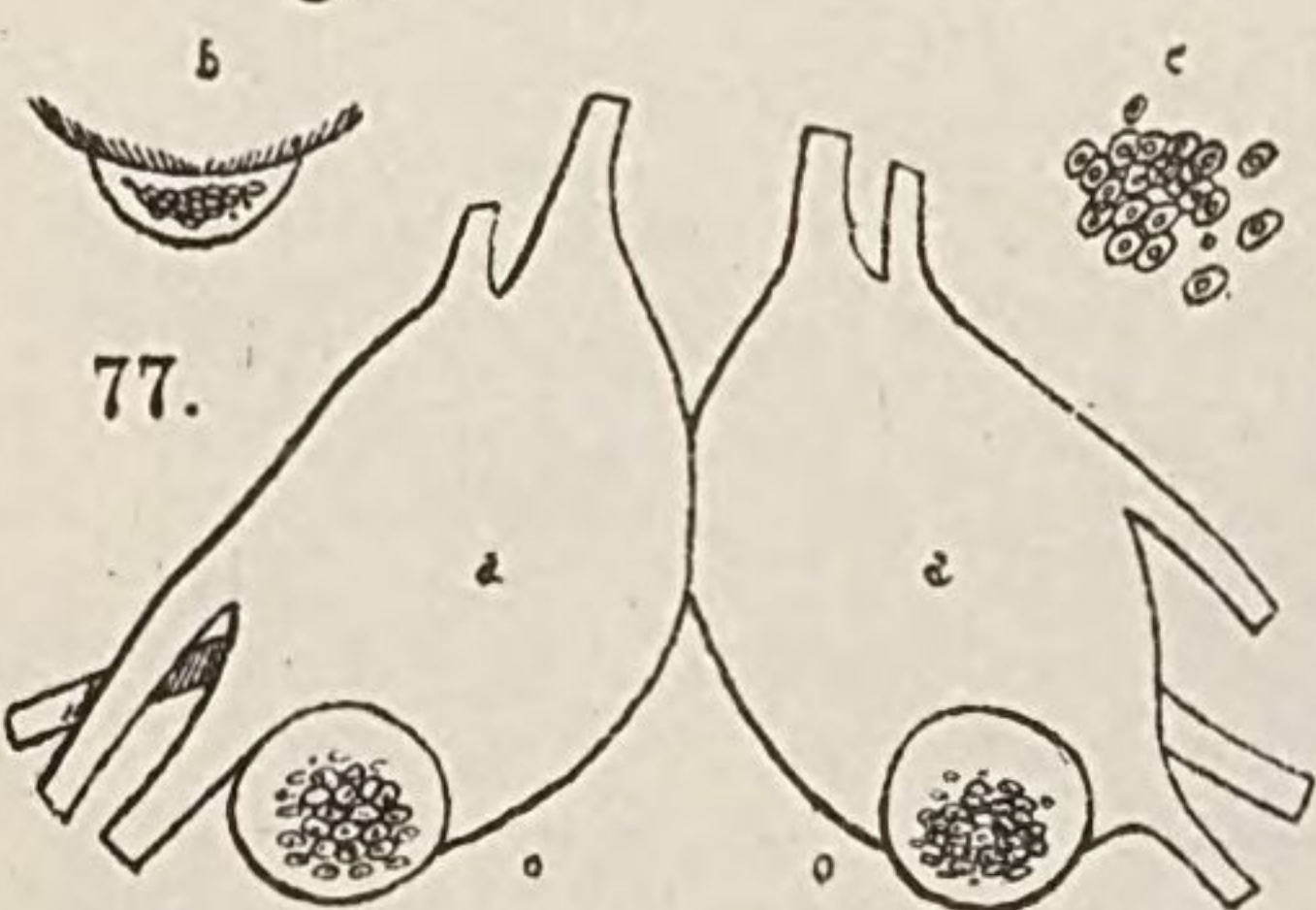
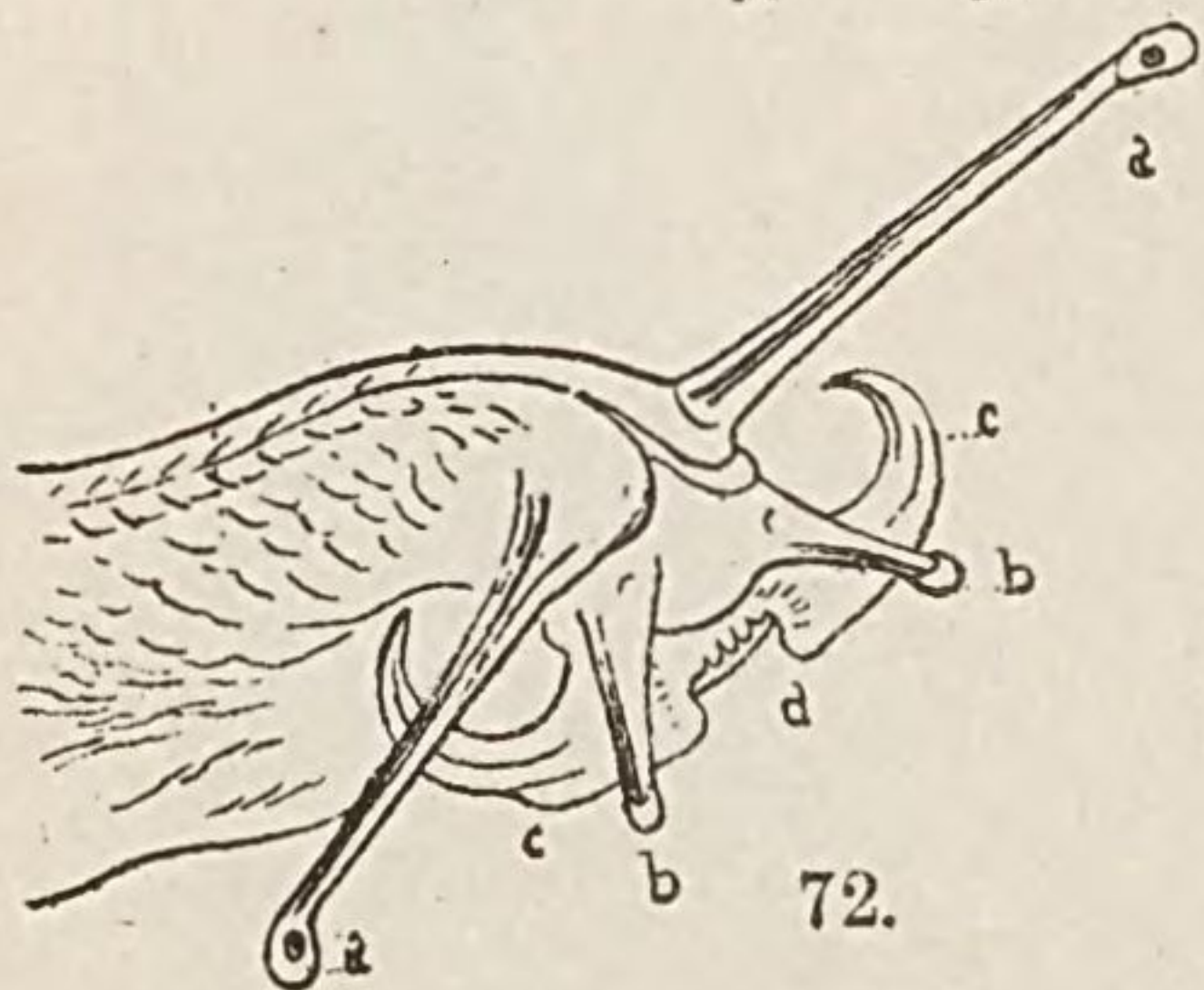
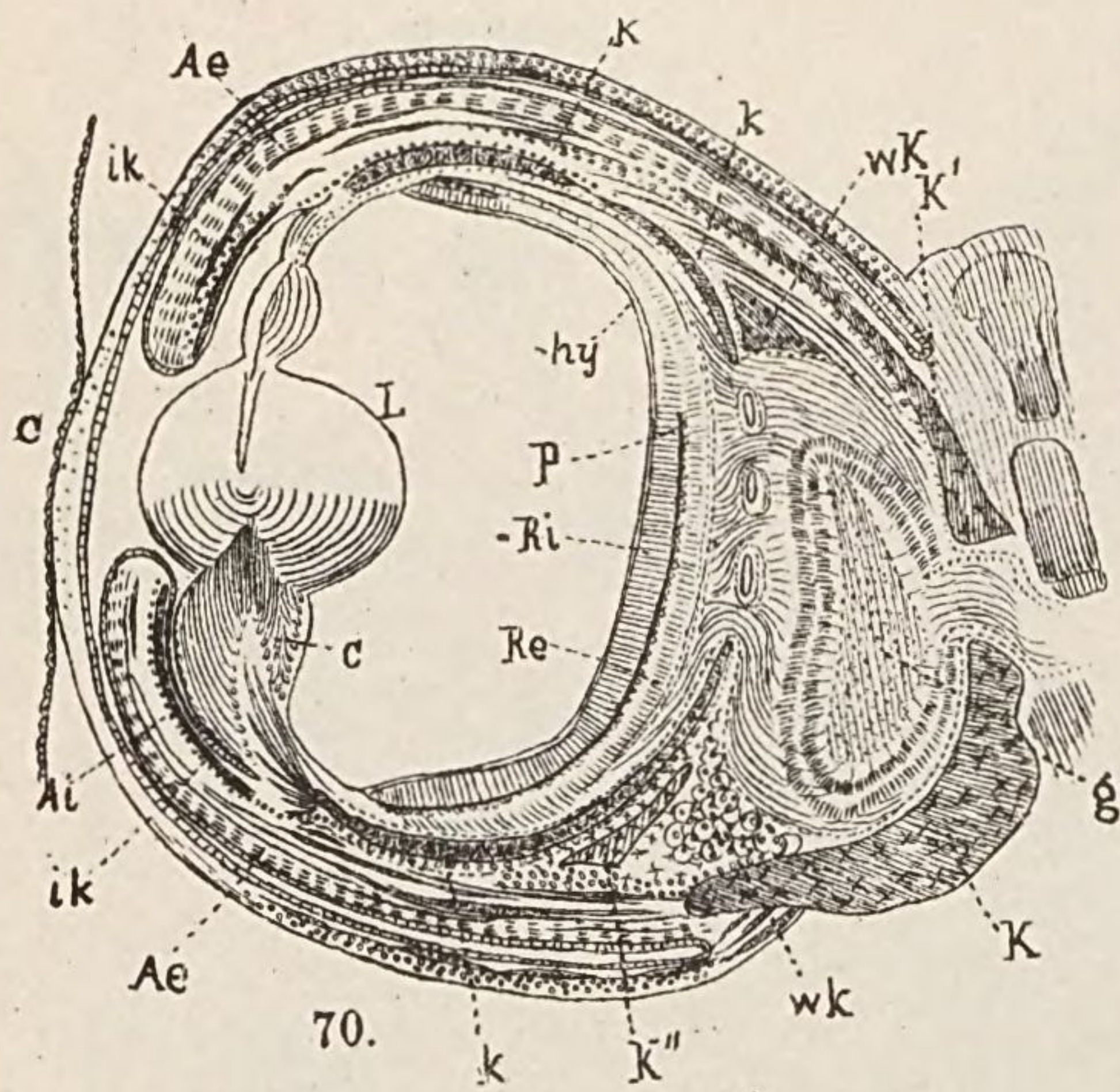
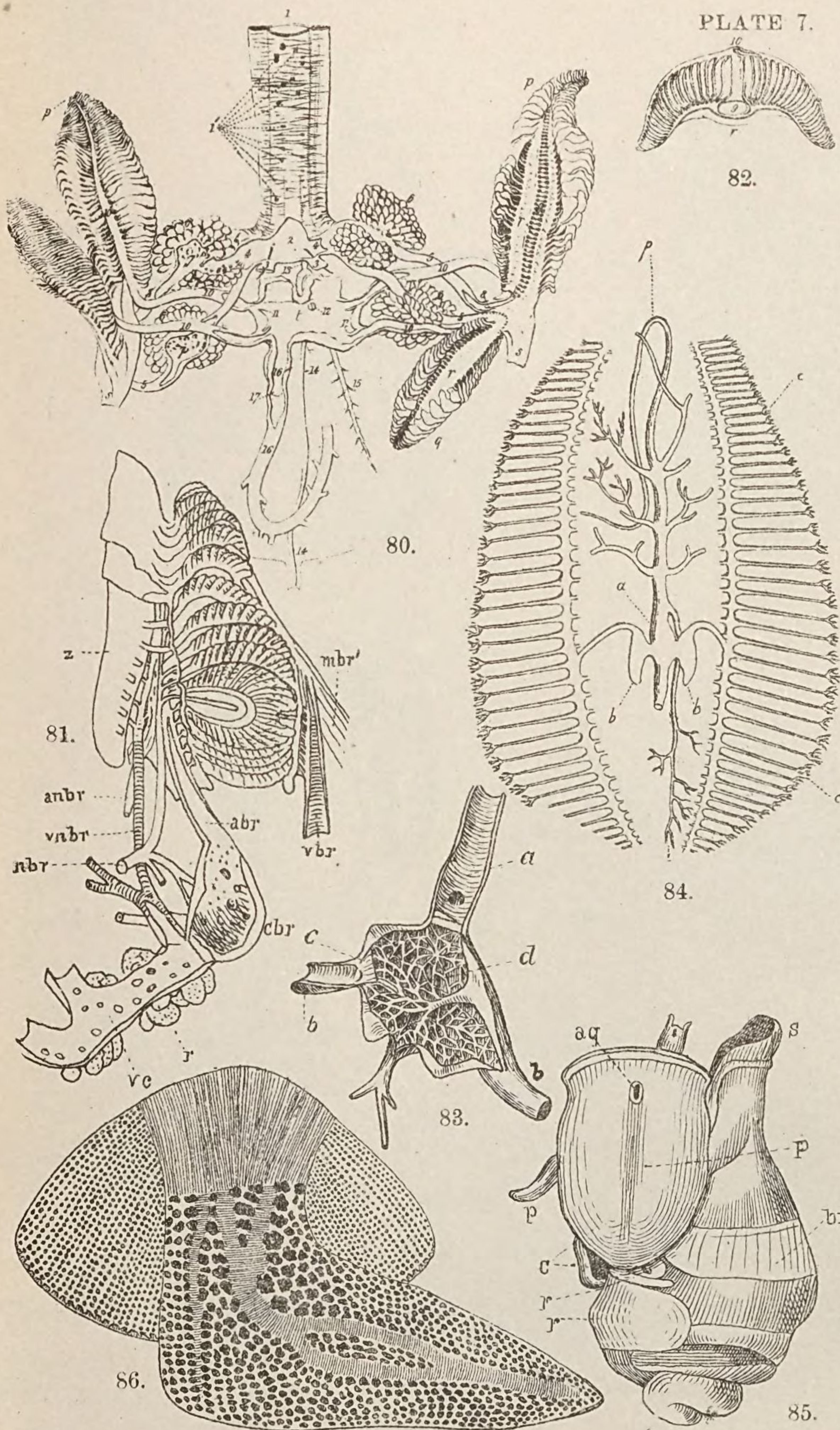
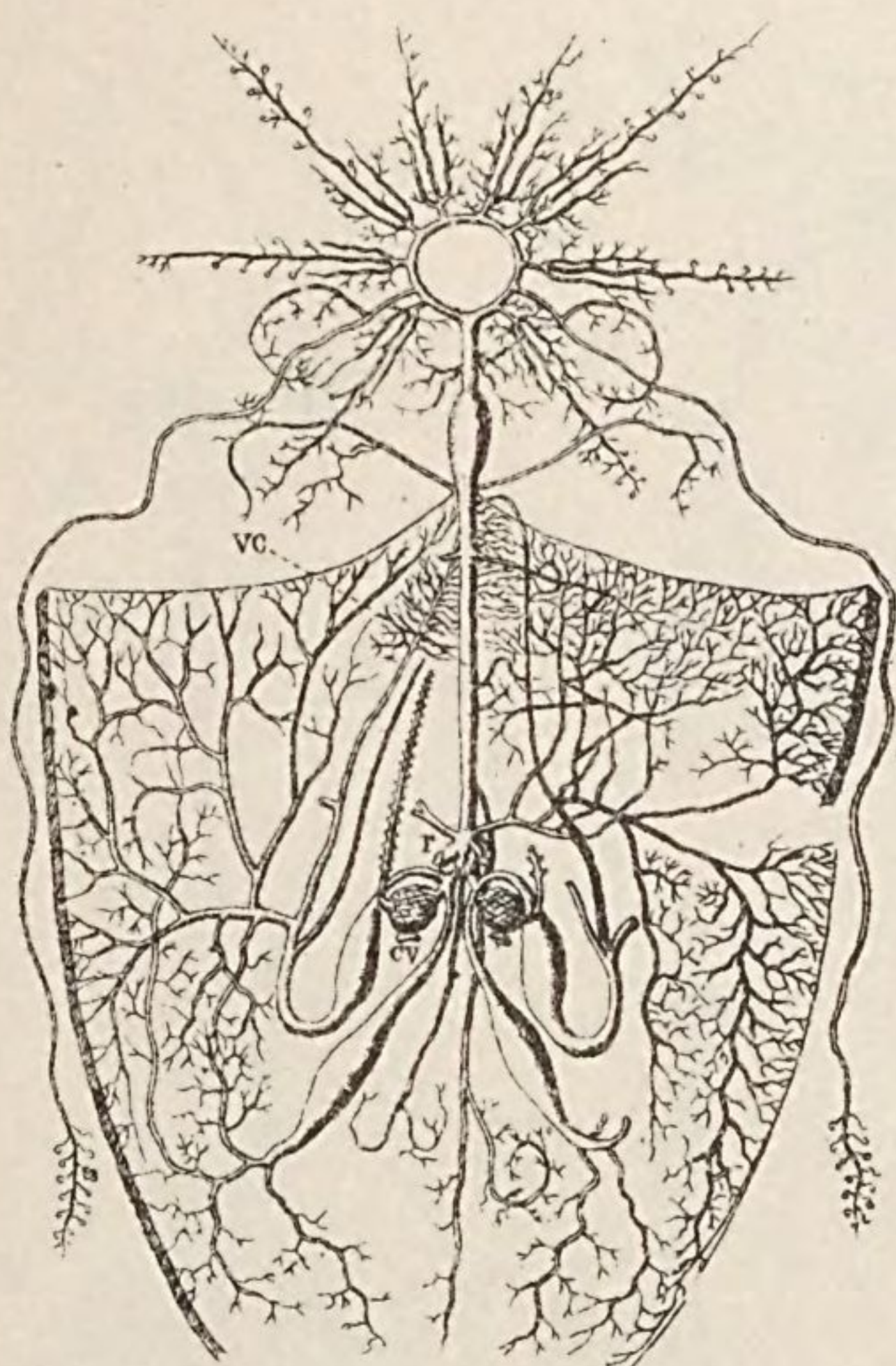
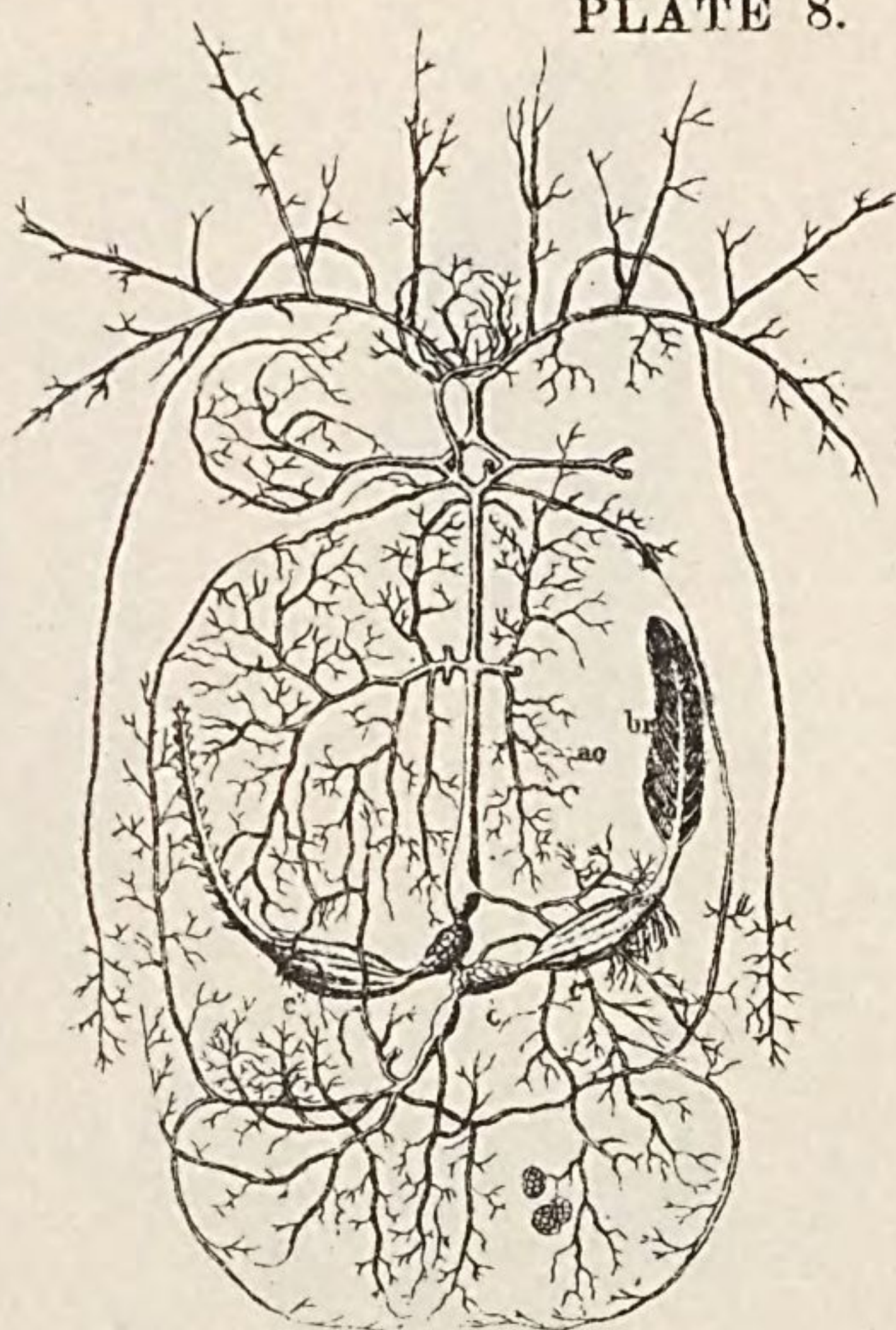


PLATE 7.

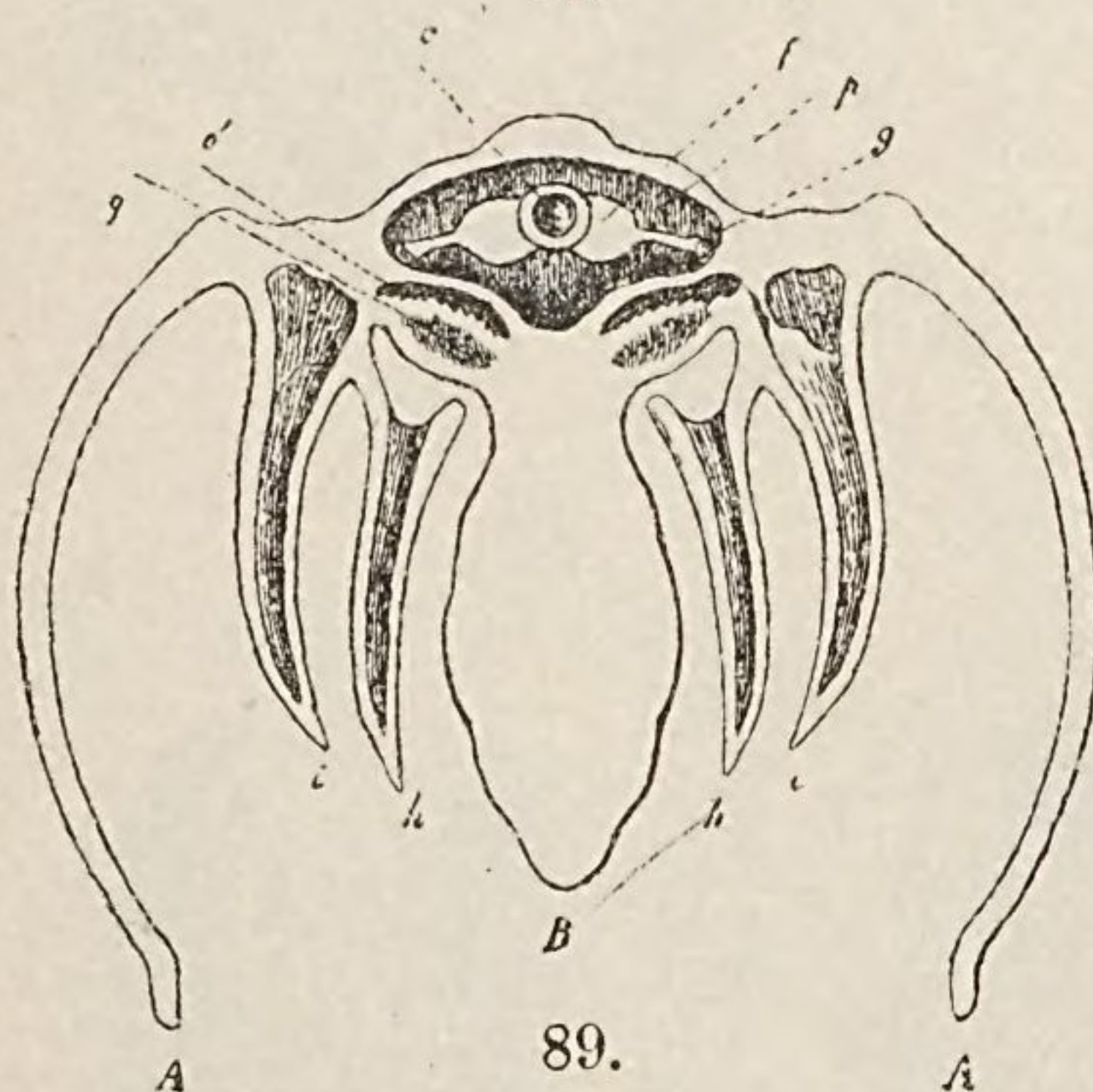




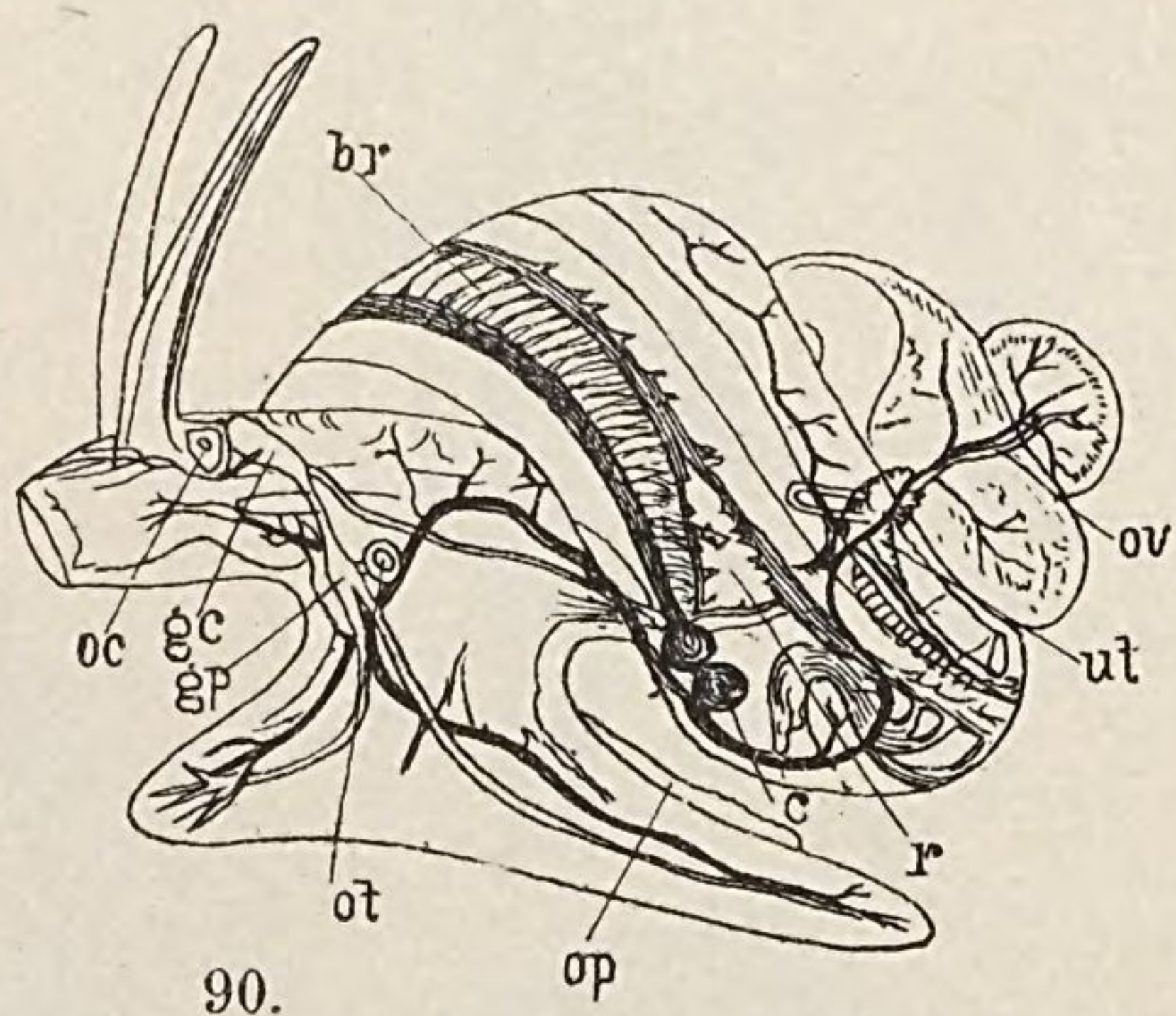
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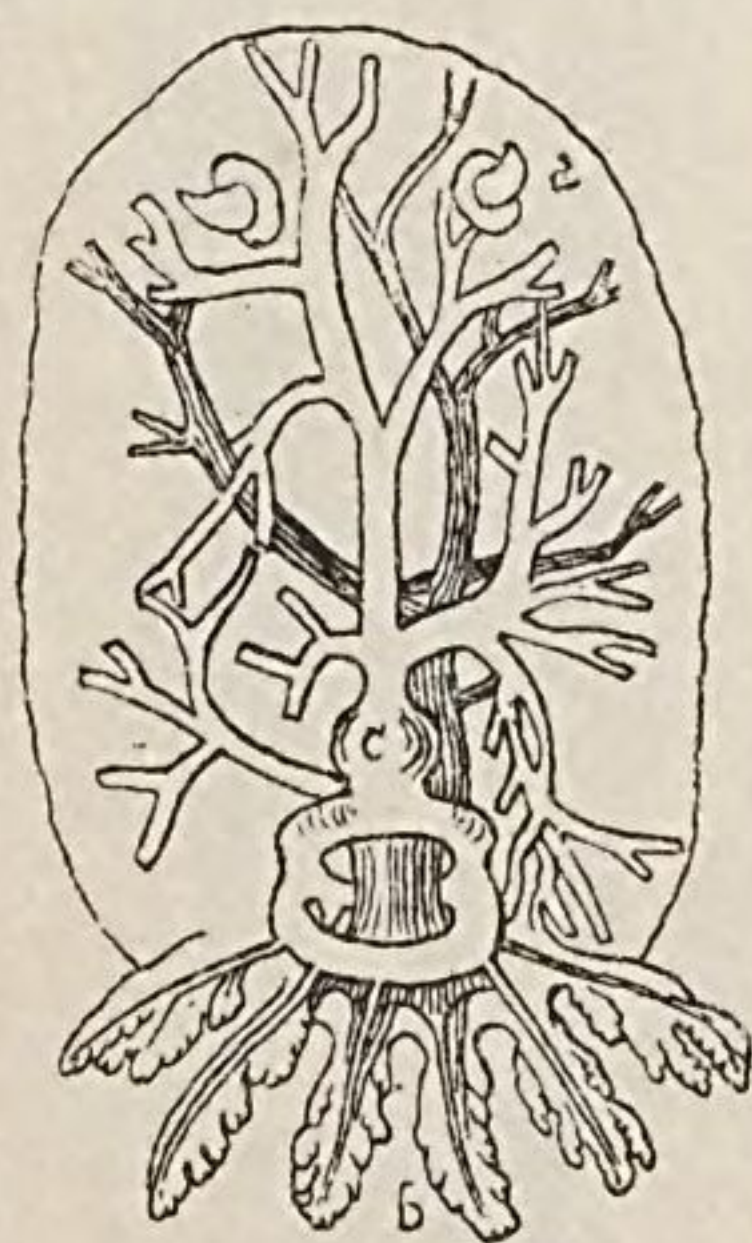
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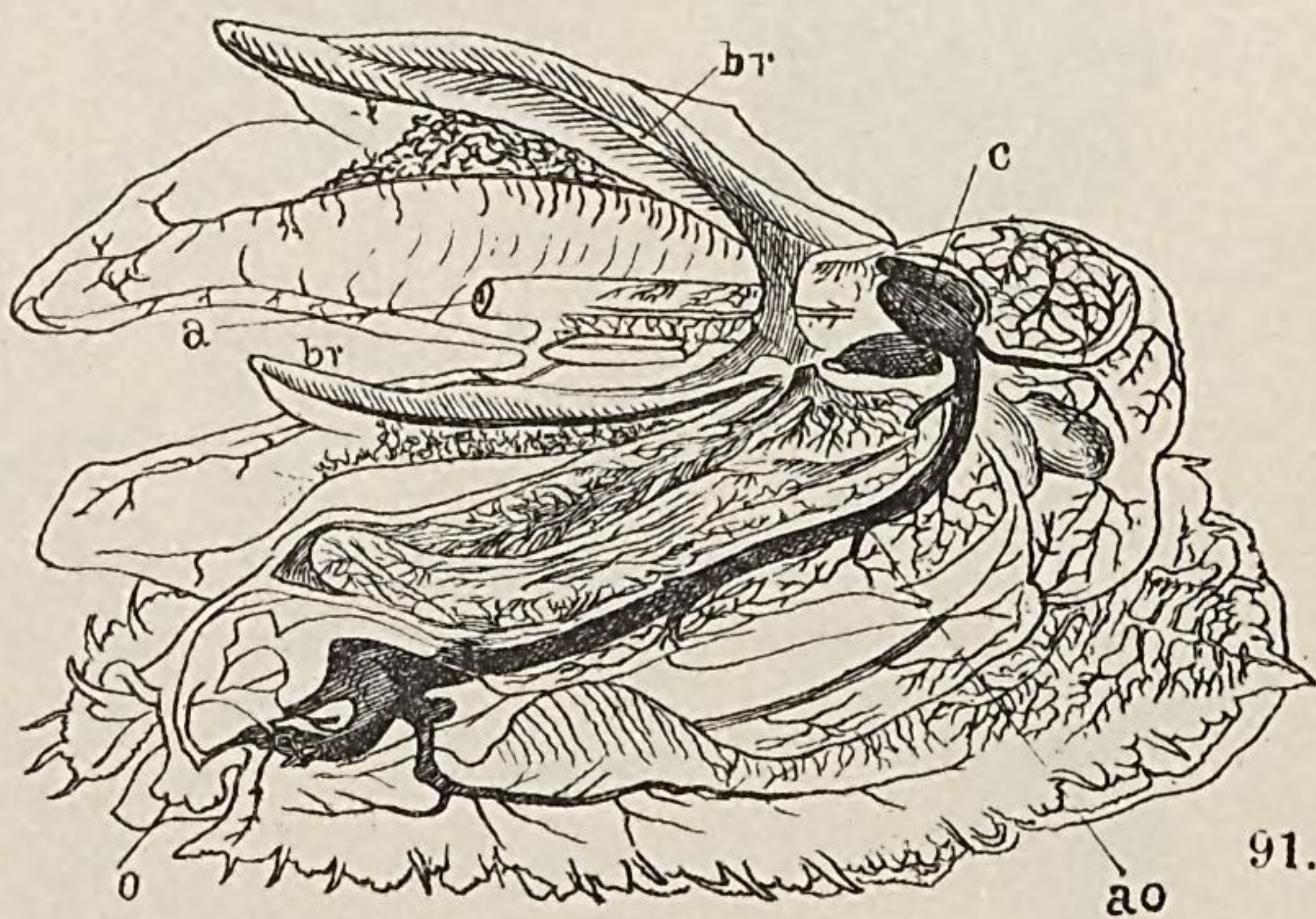
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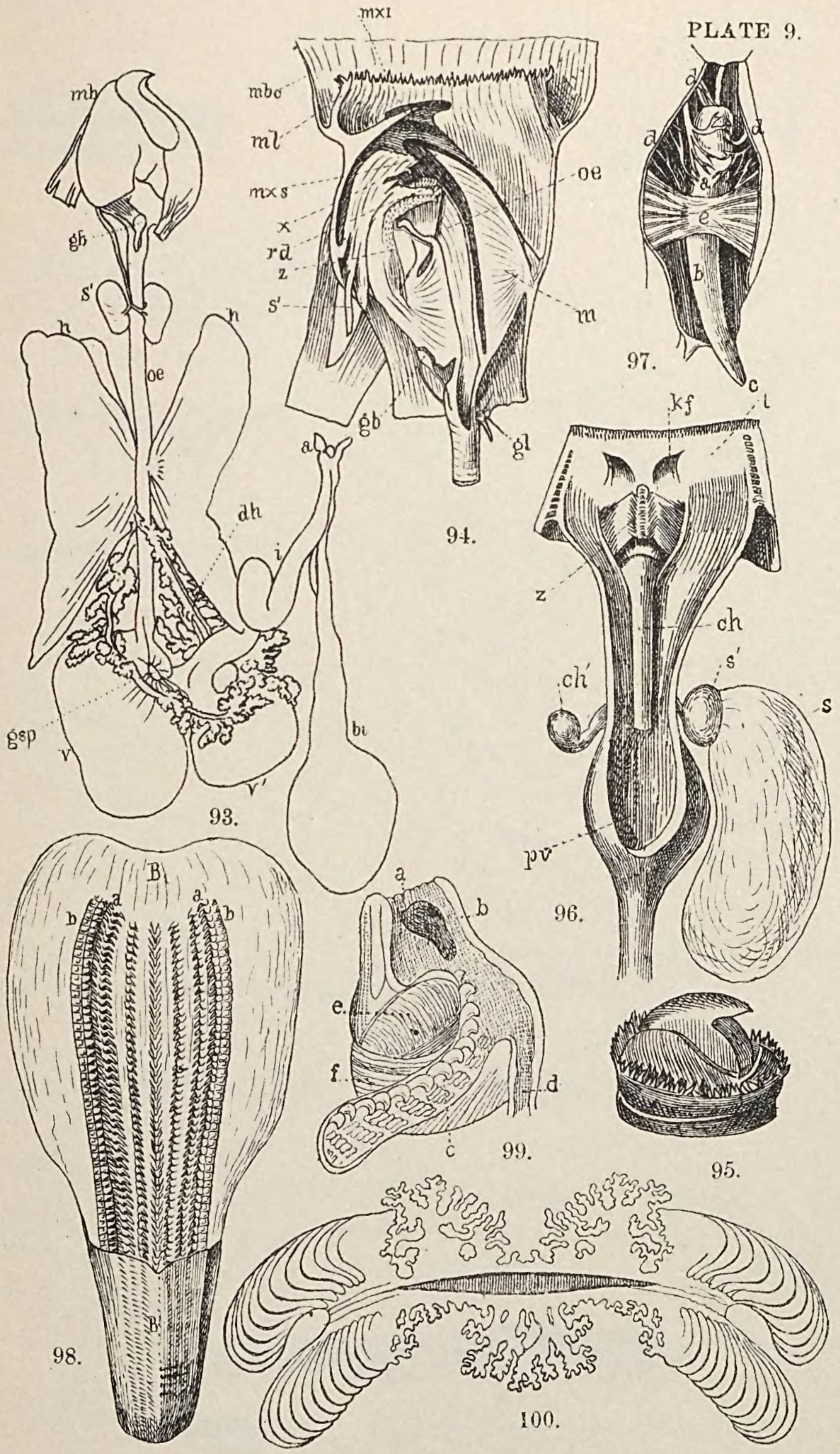
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92.



91.



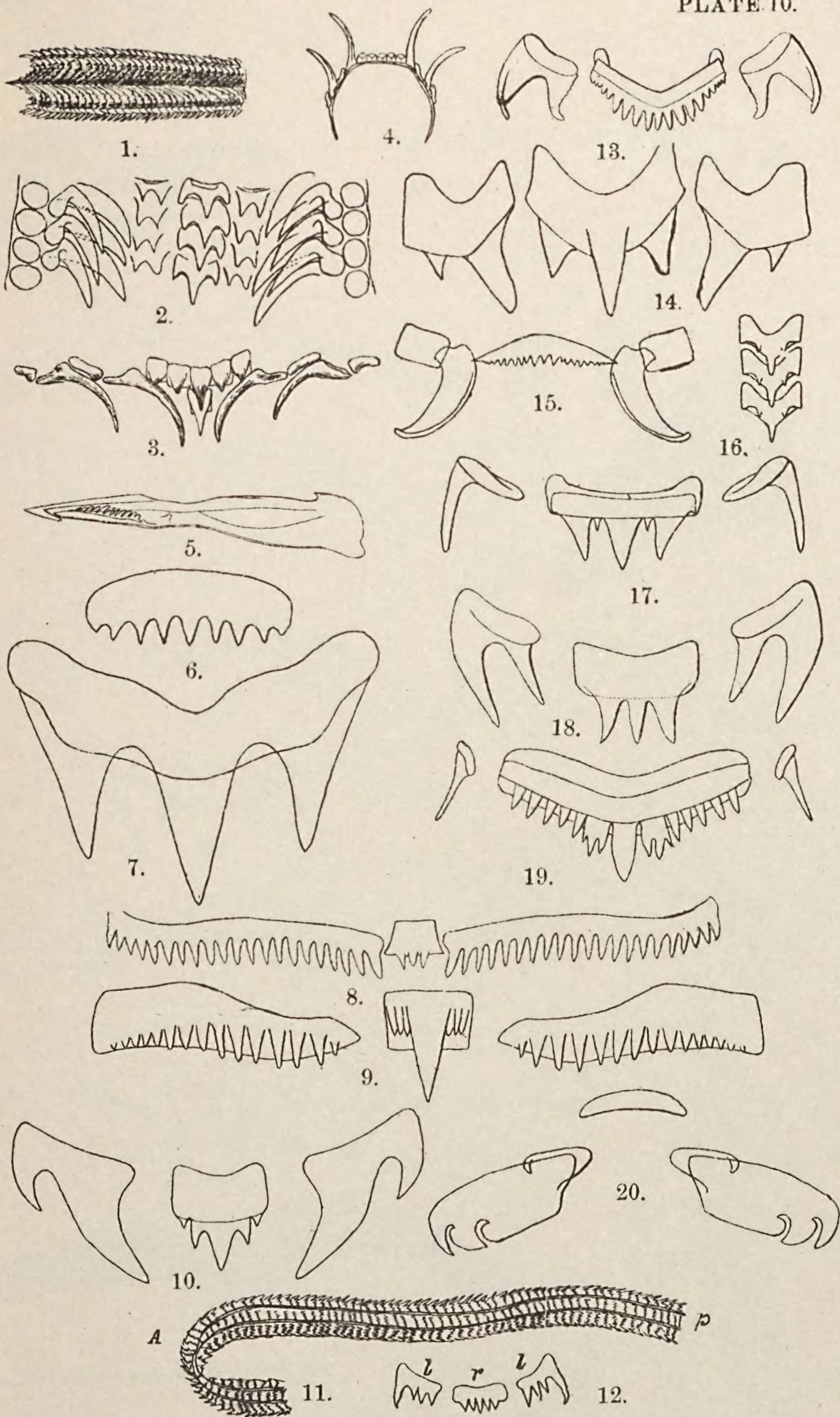
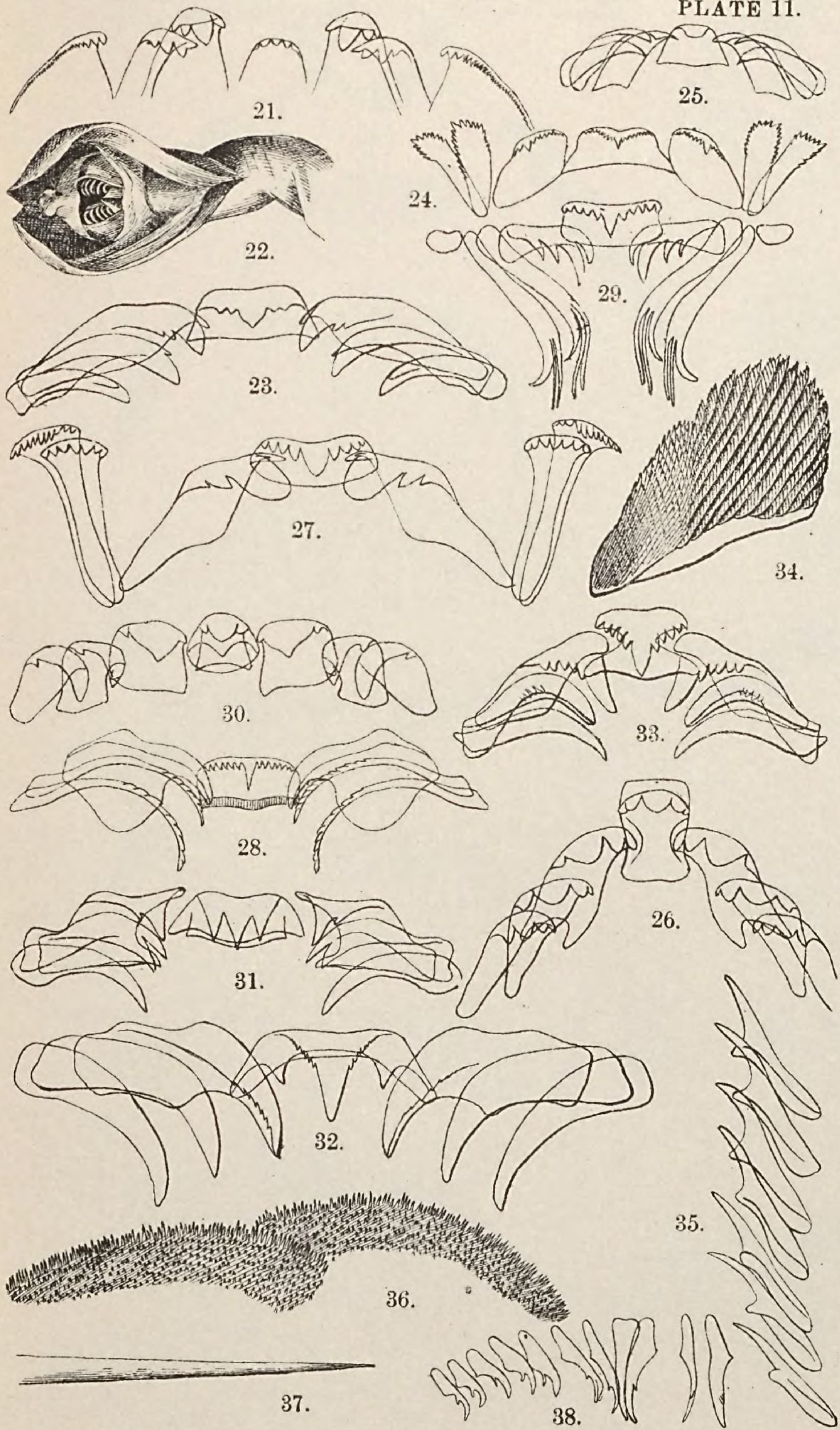
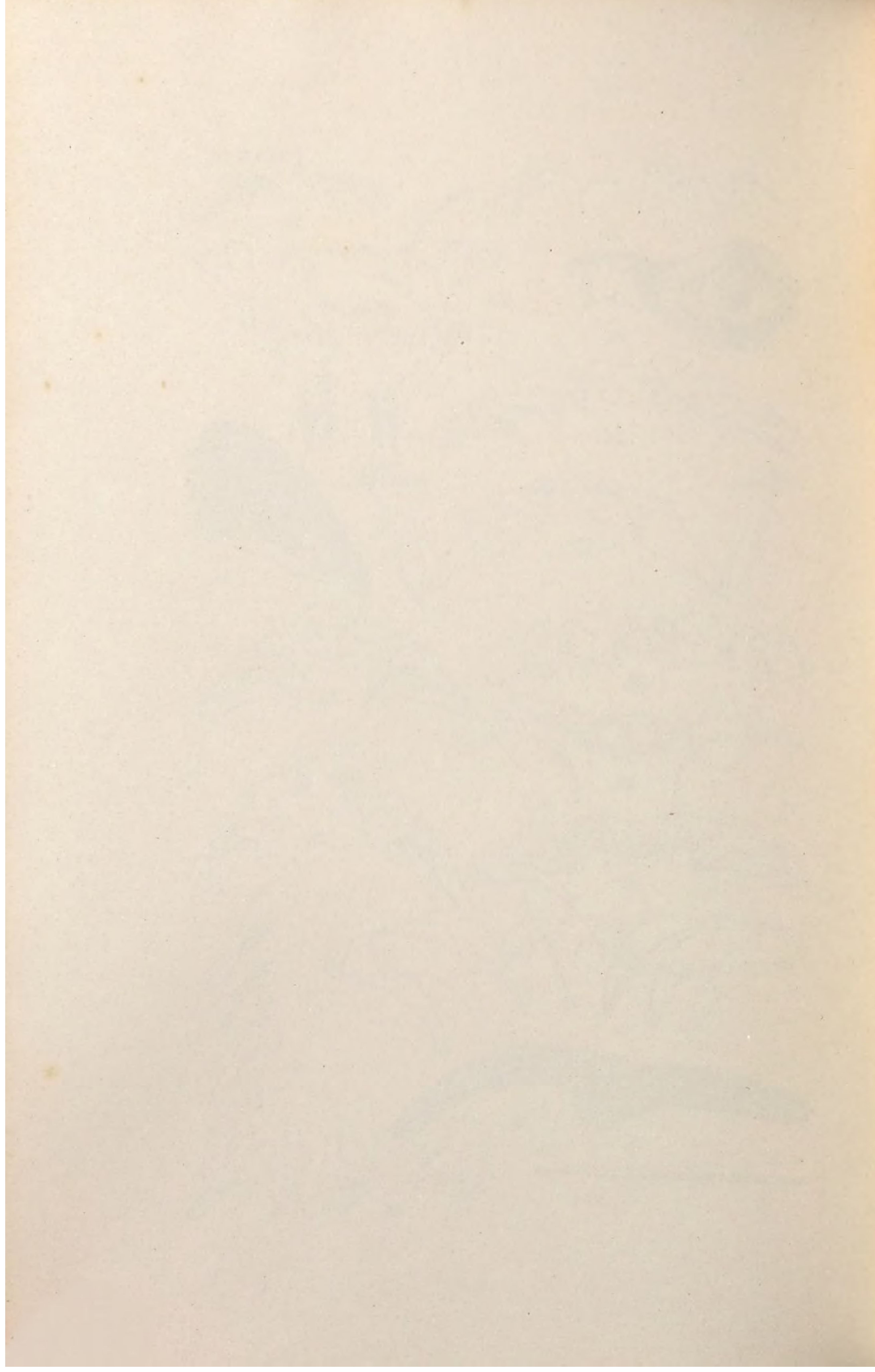
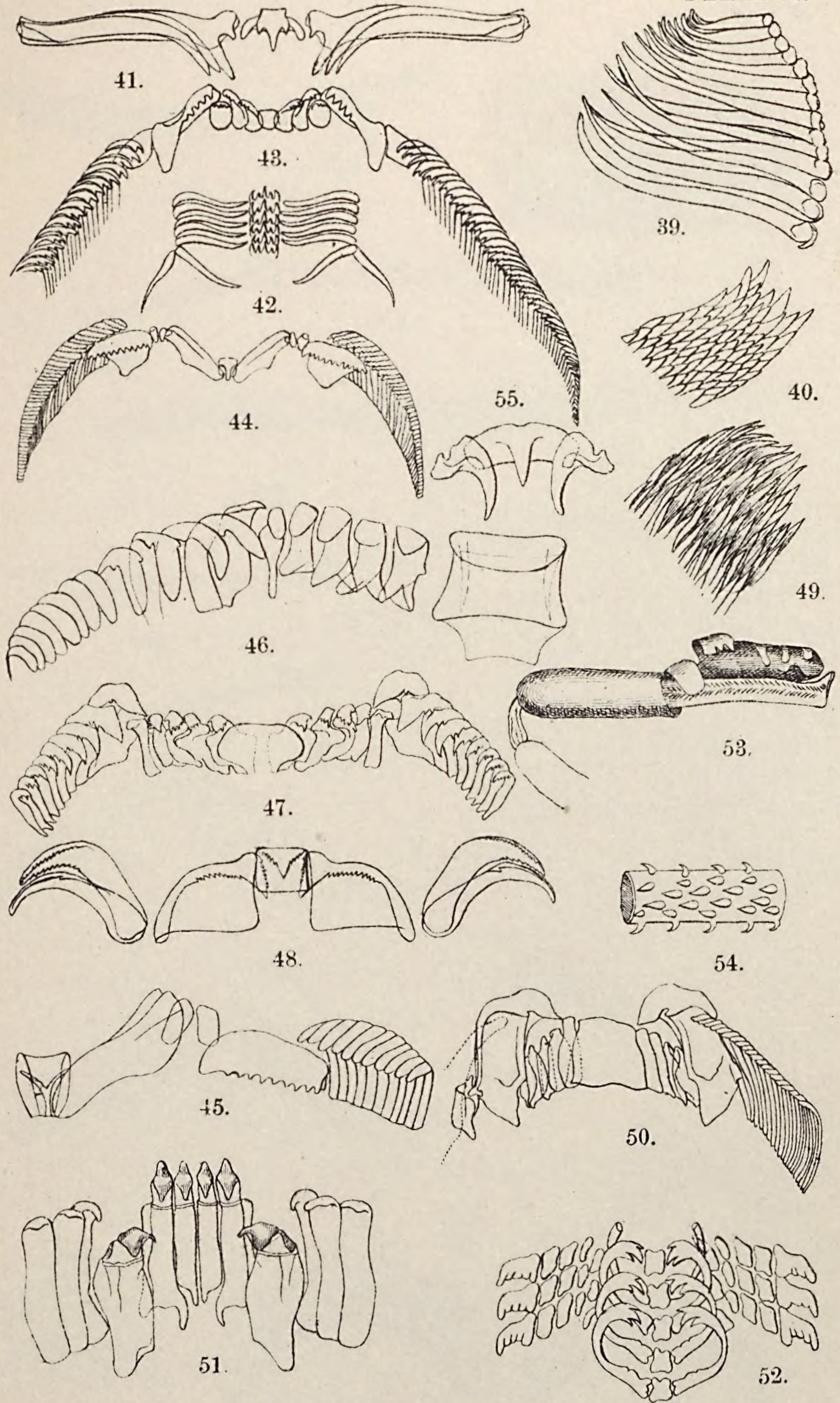


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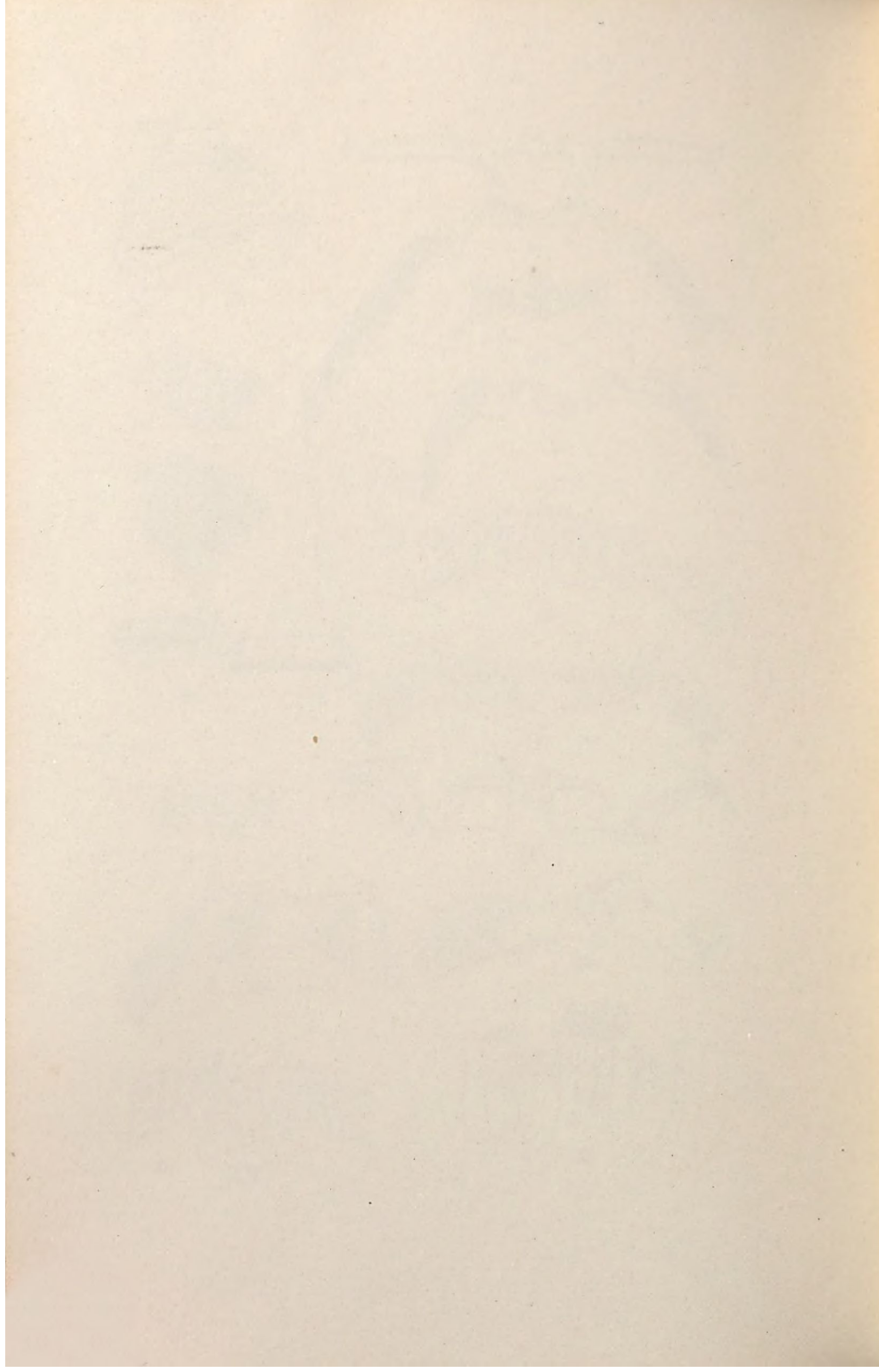
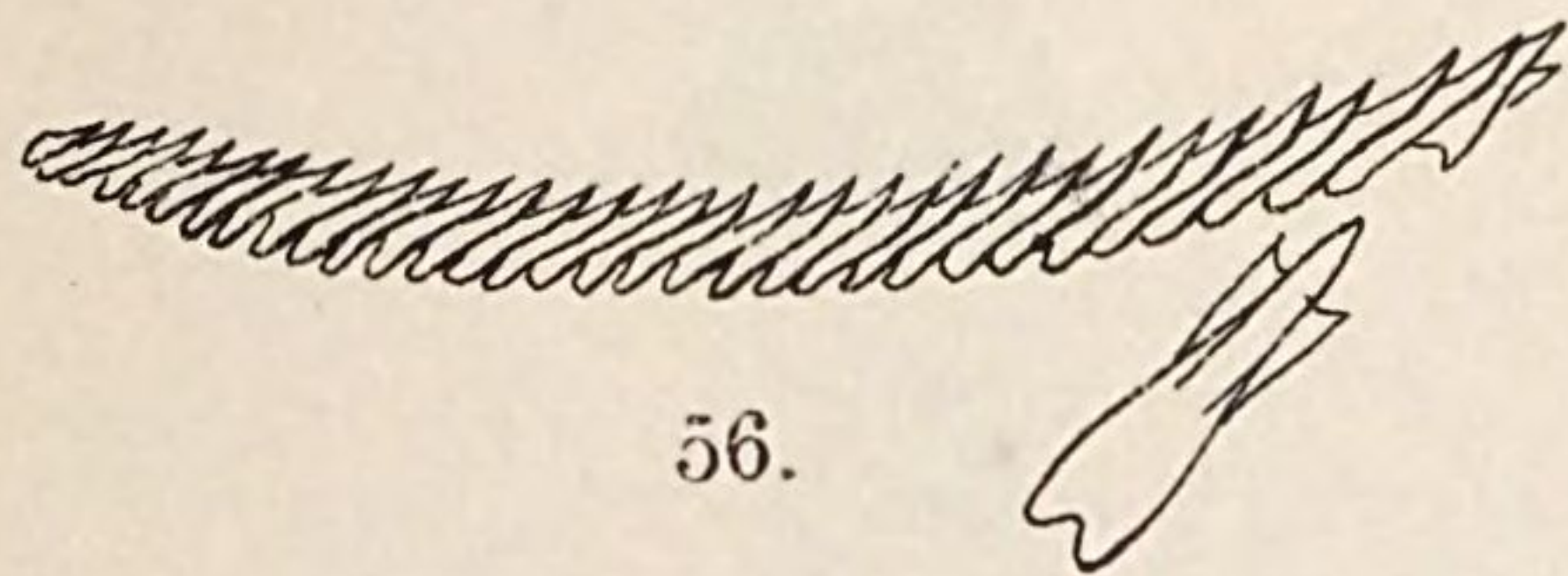
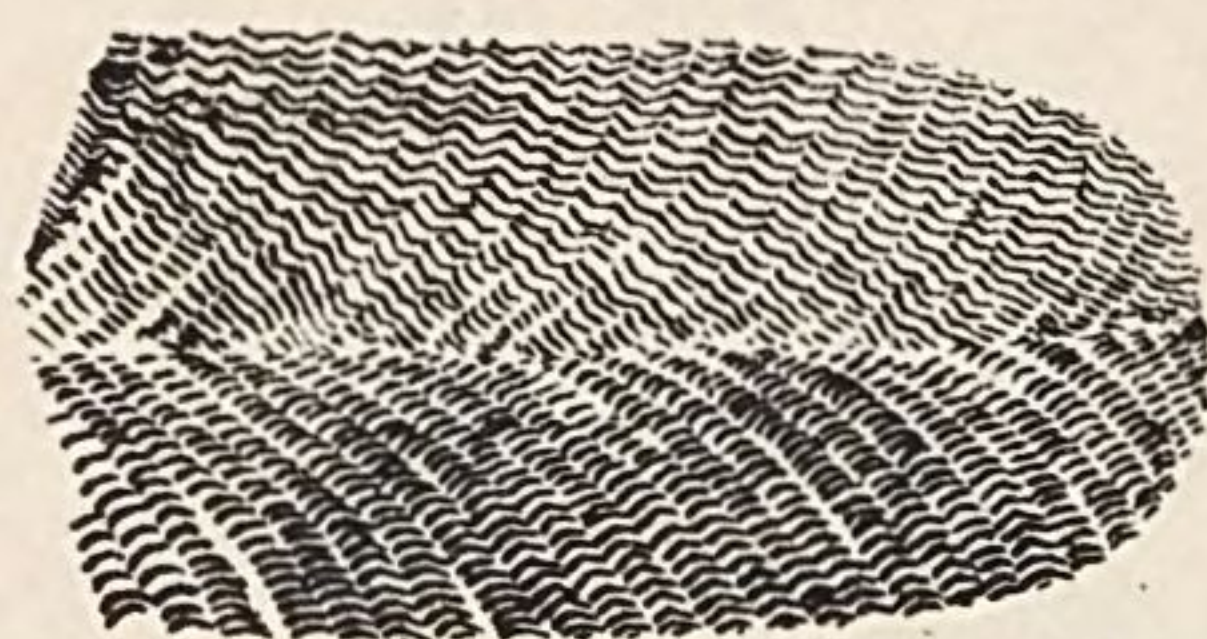


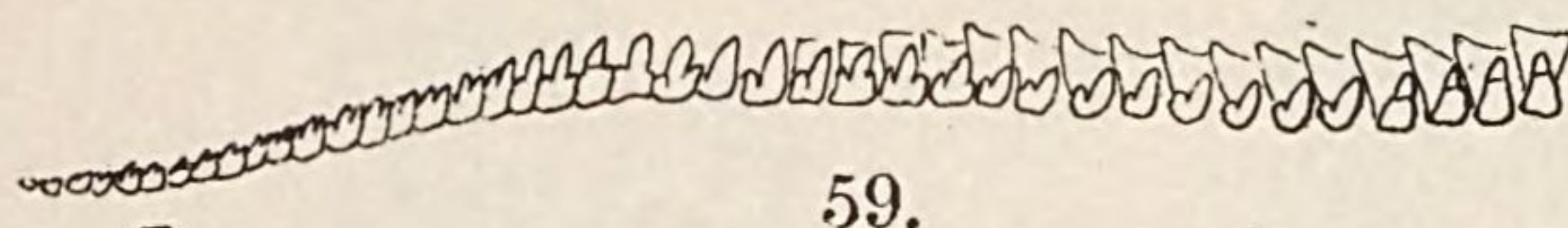
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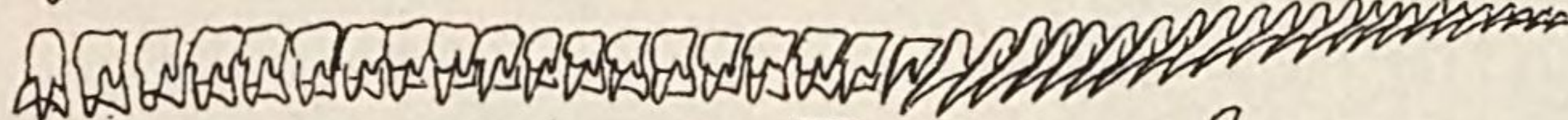
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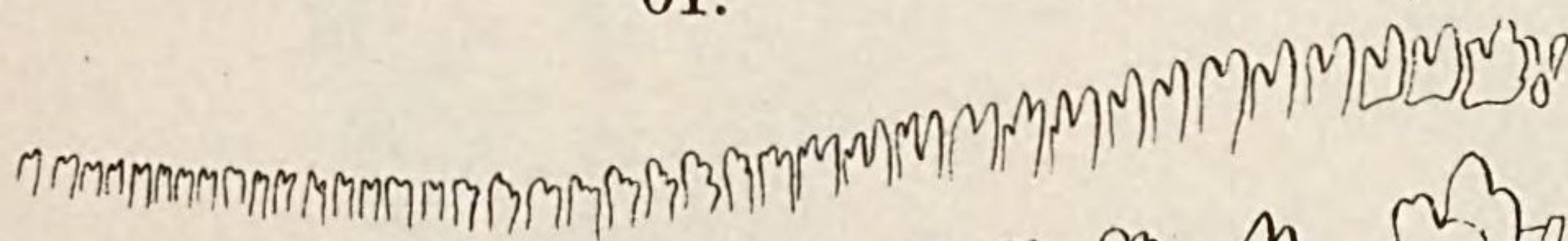
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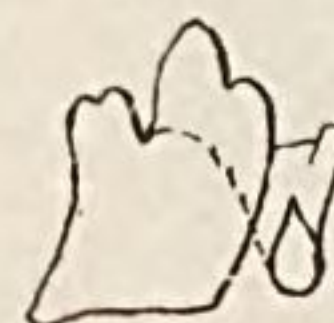
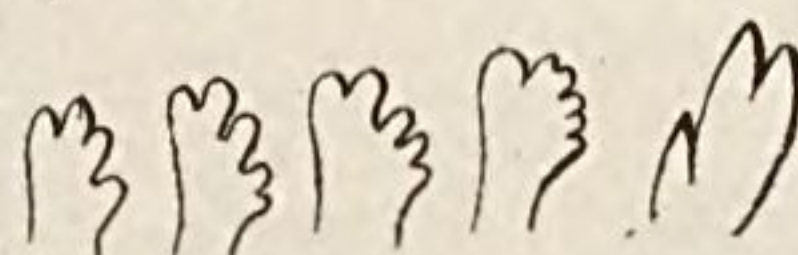
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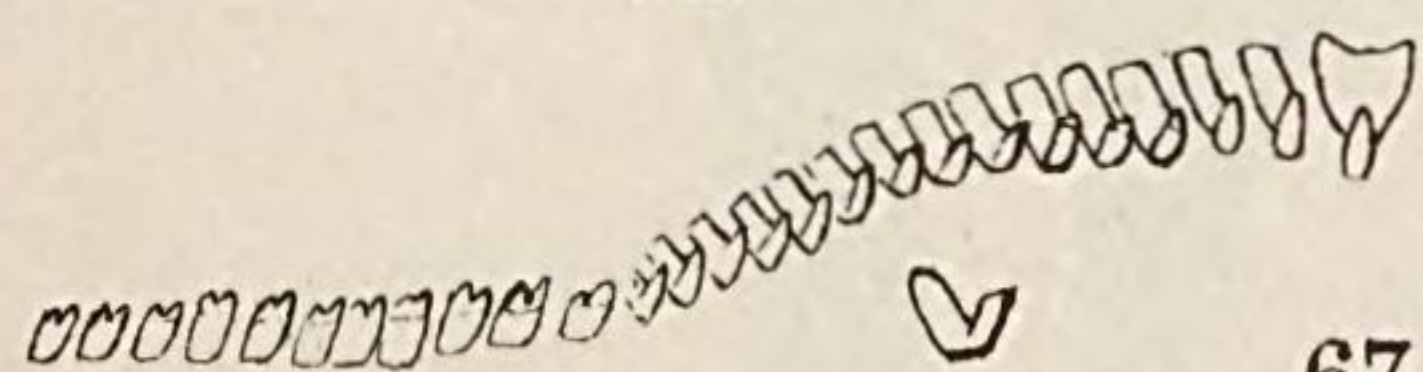
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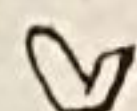
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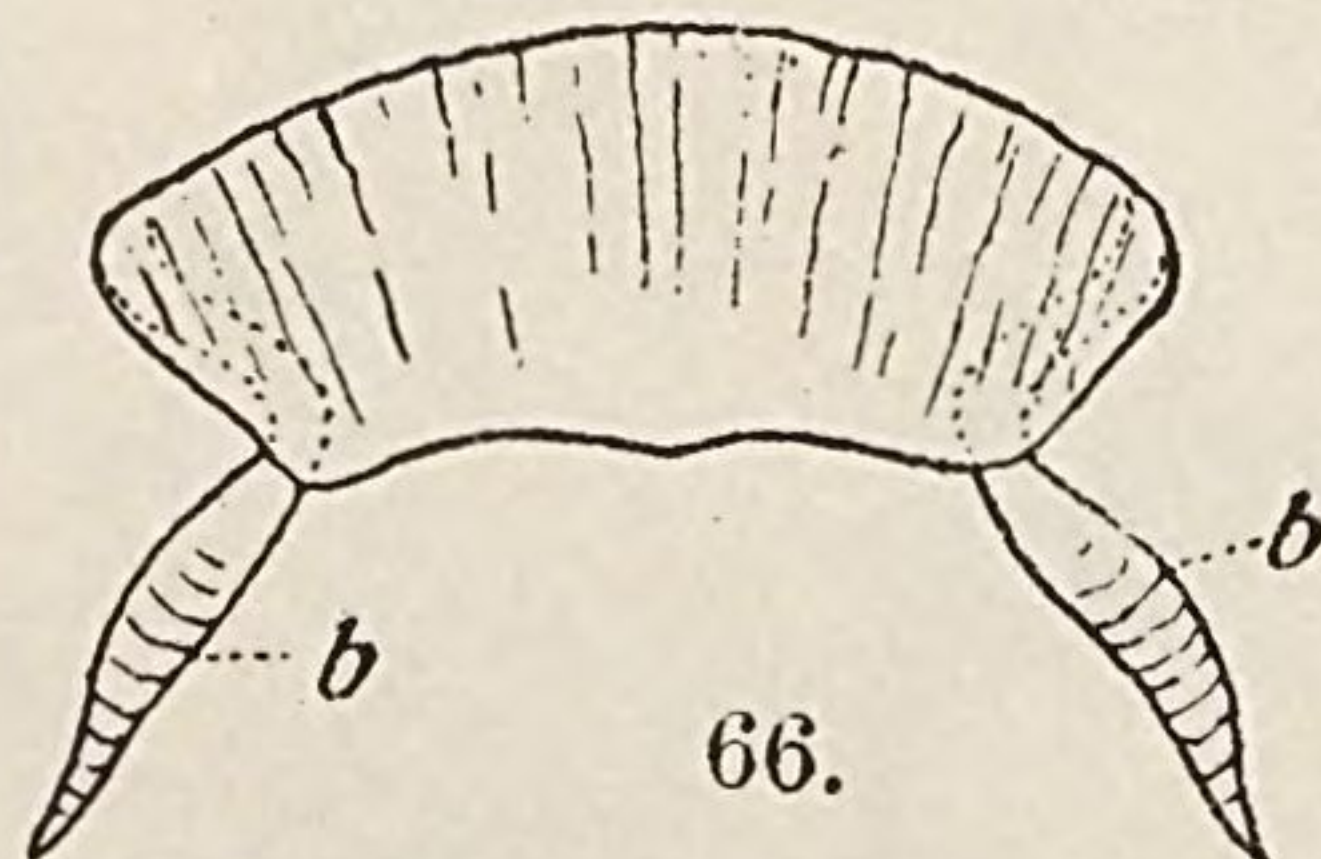
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67.



68.



66.

b

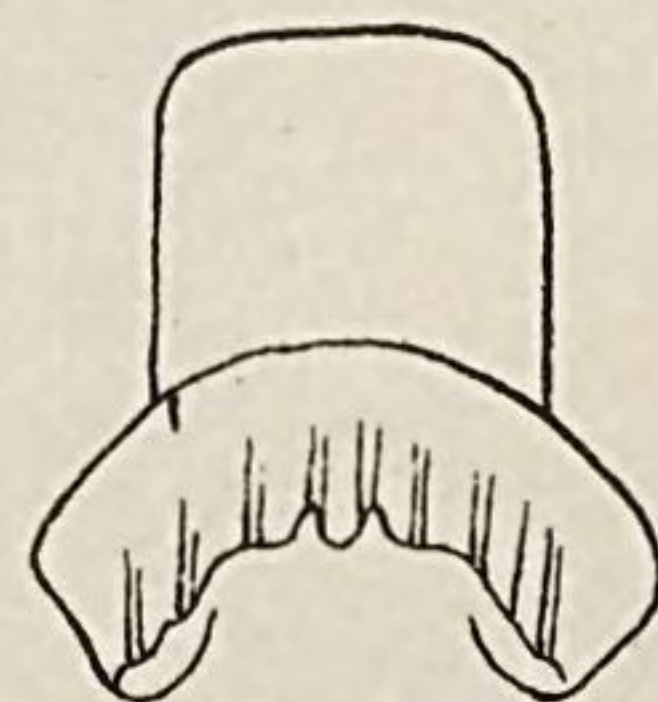
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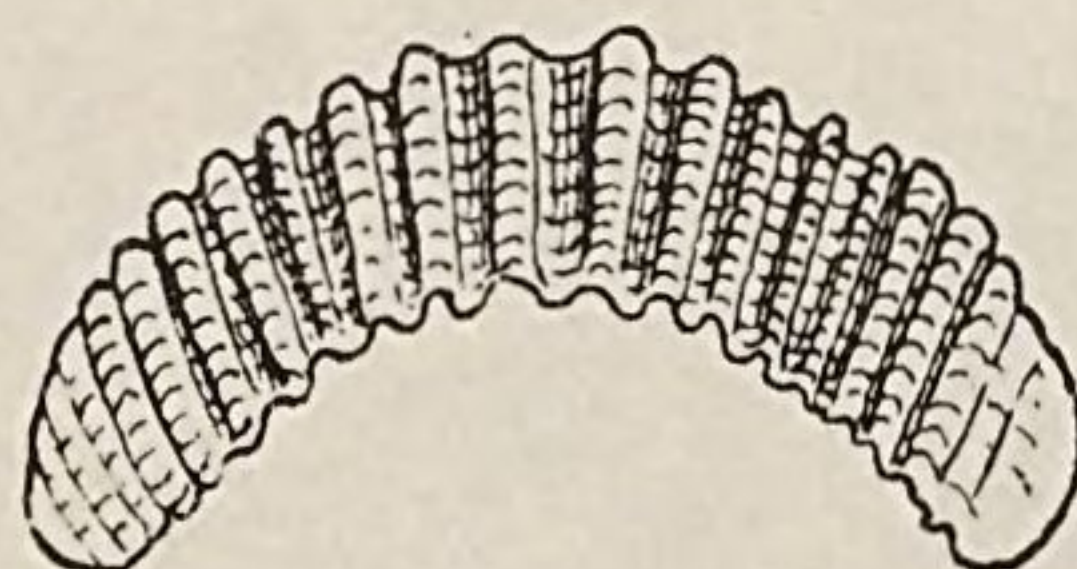
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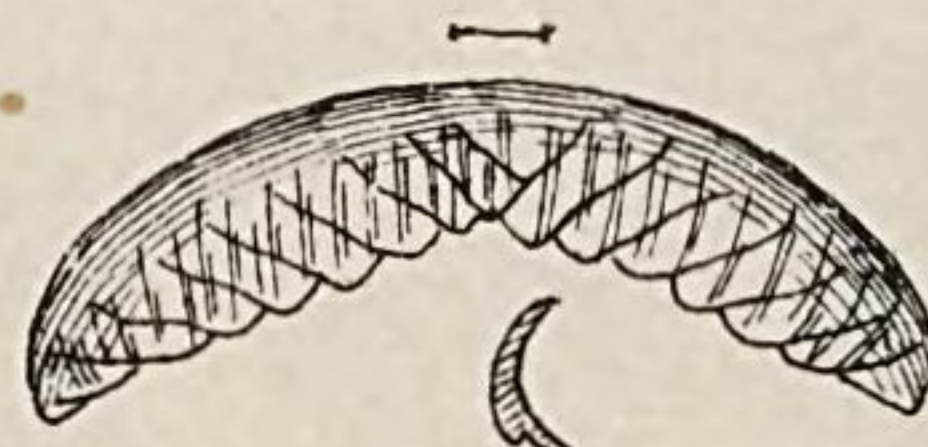
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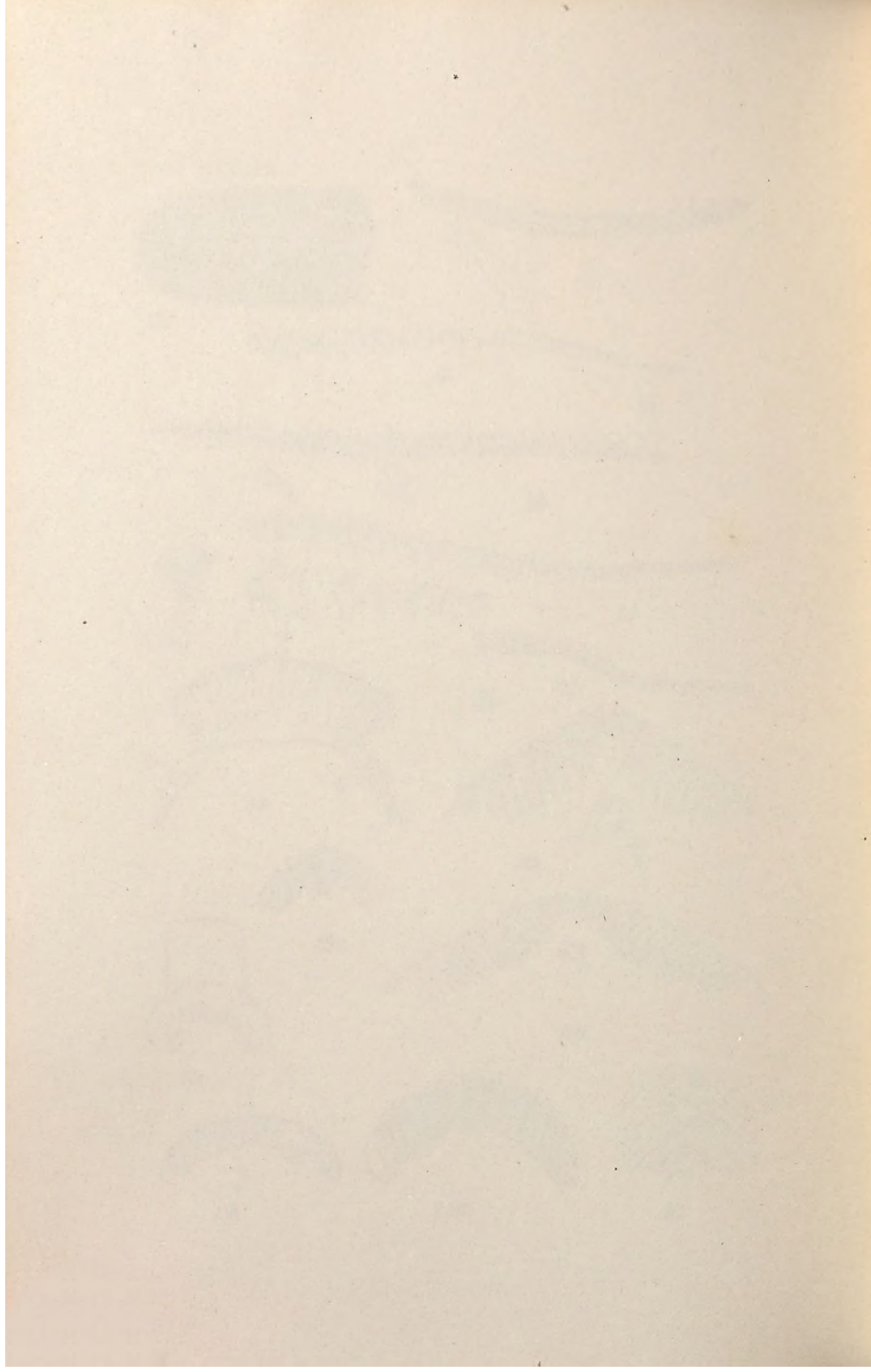
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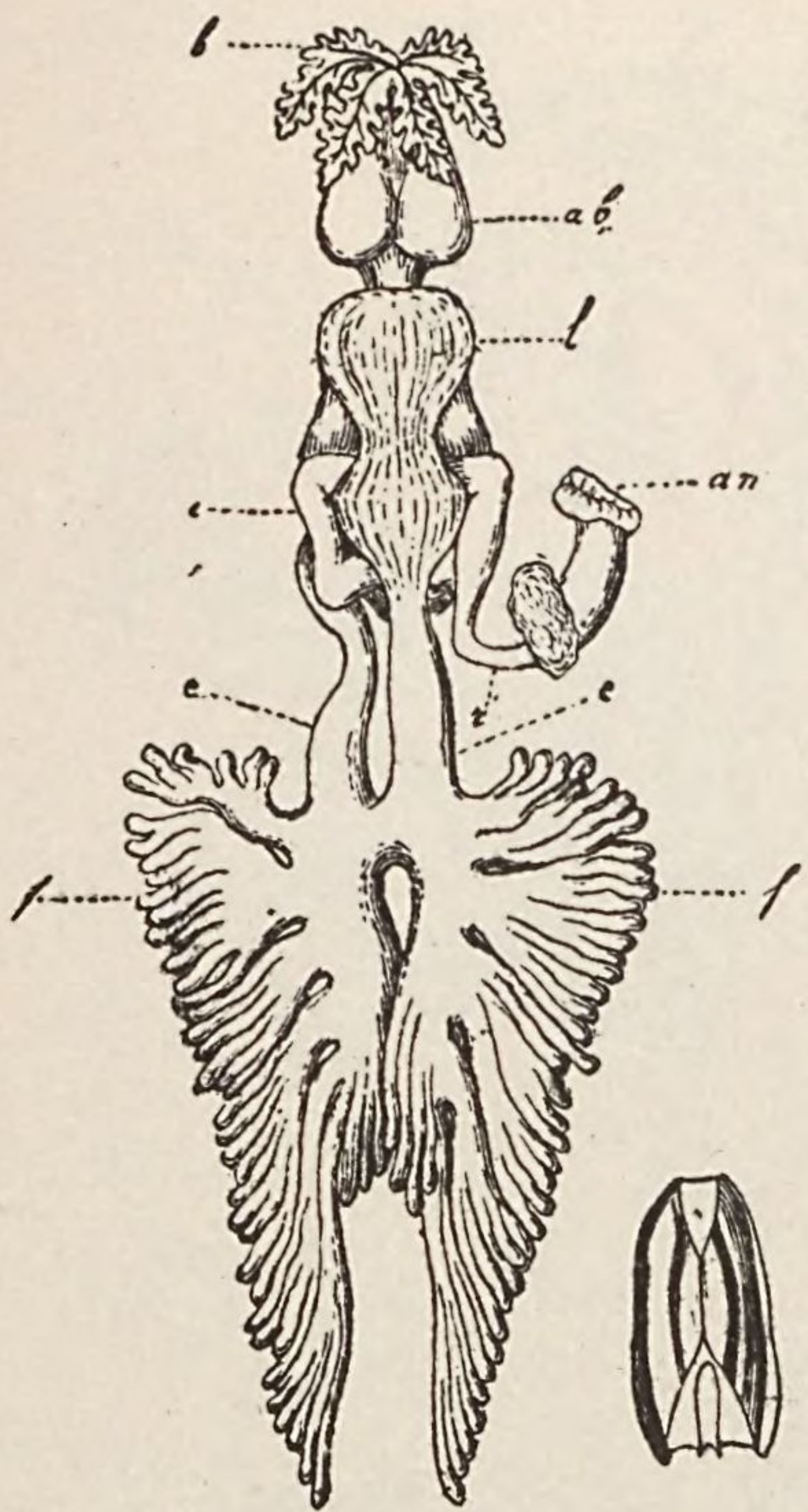


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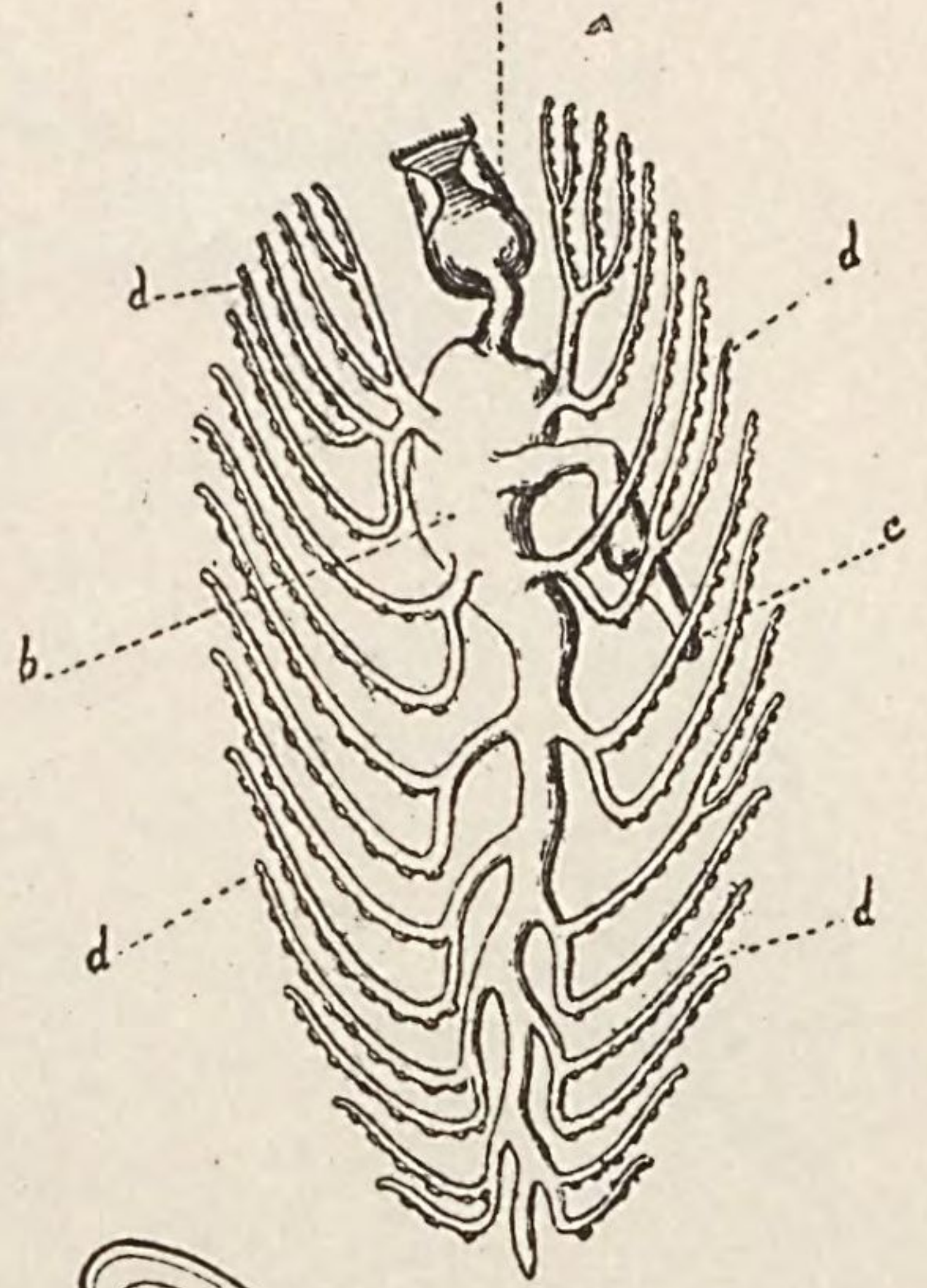


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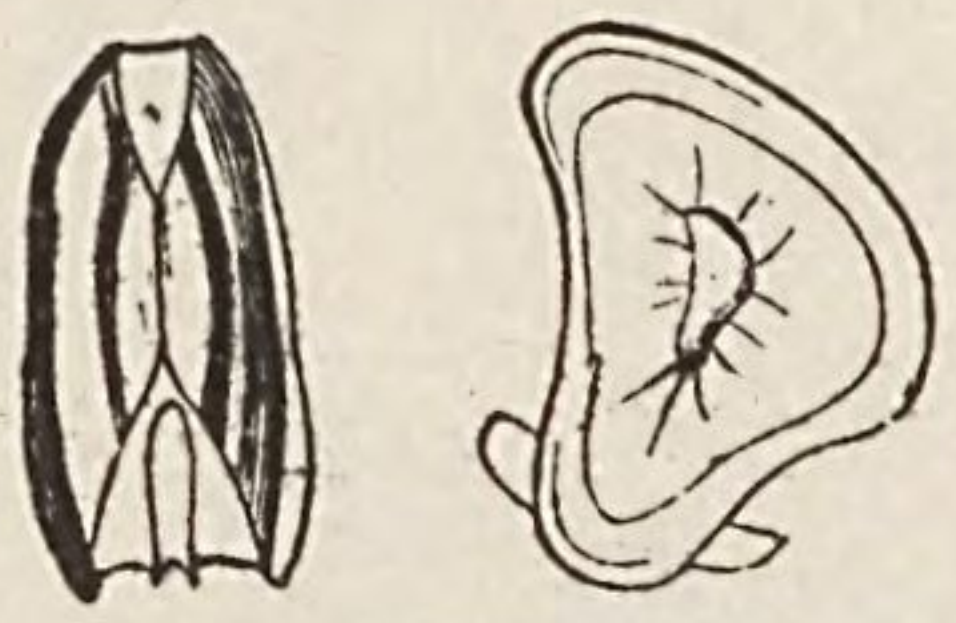




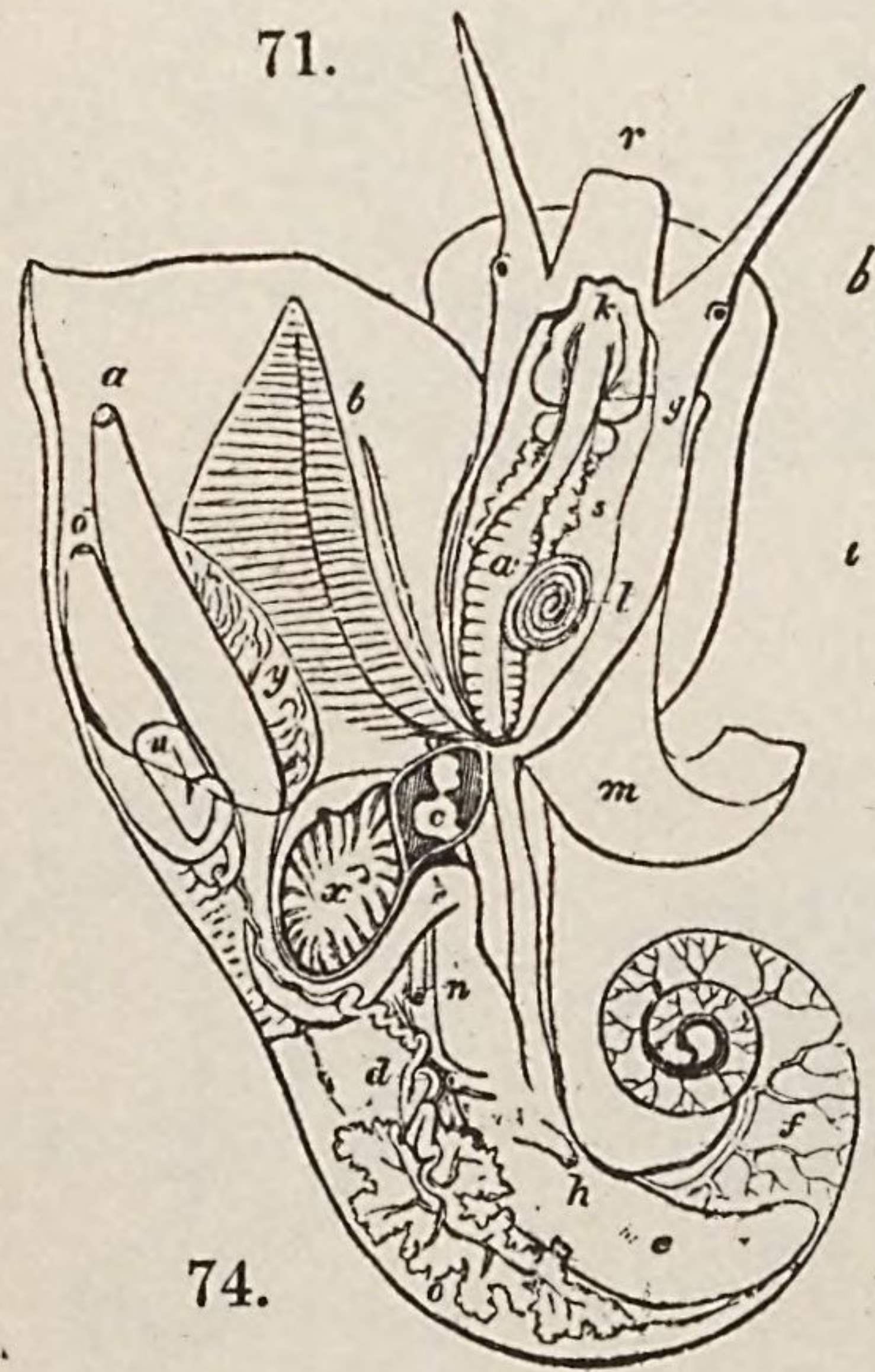
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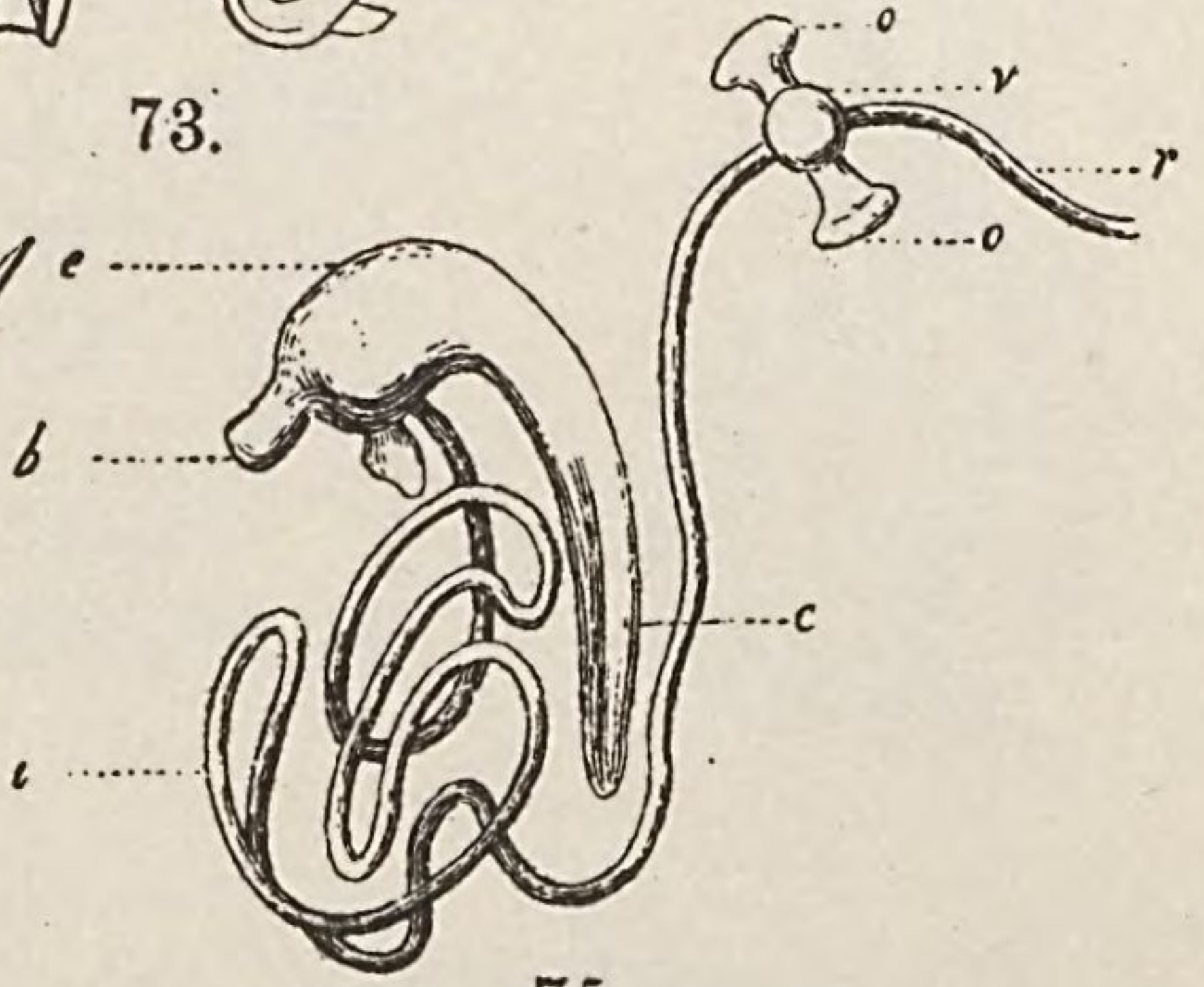
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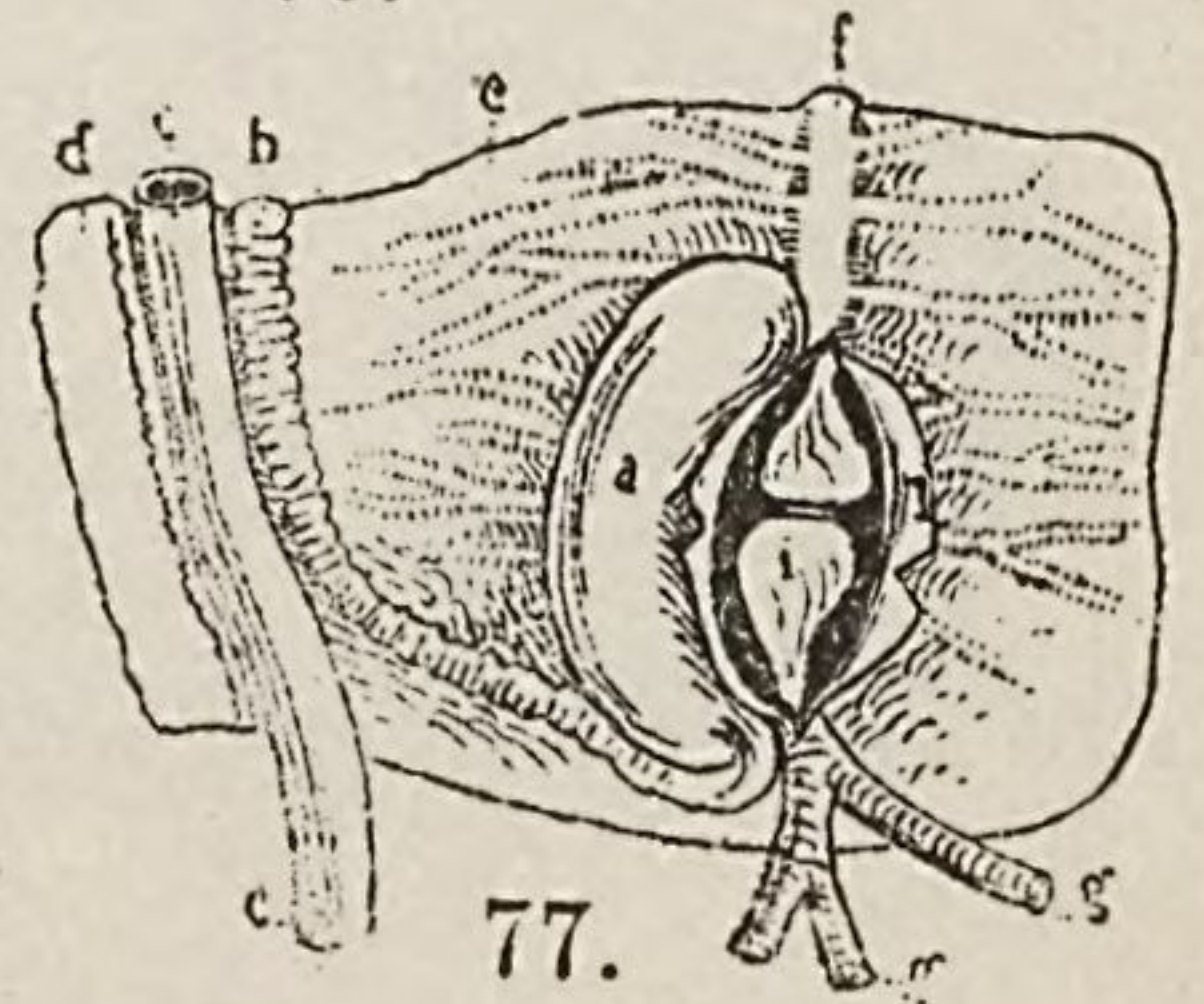
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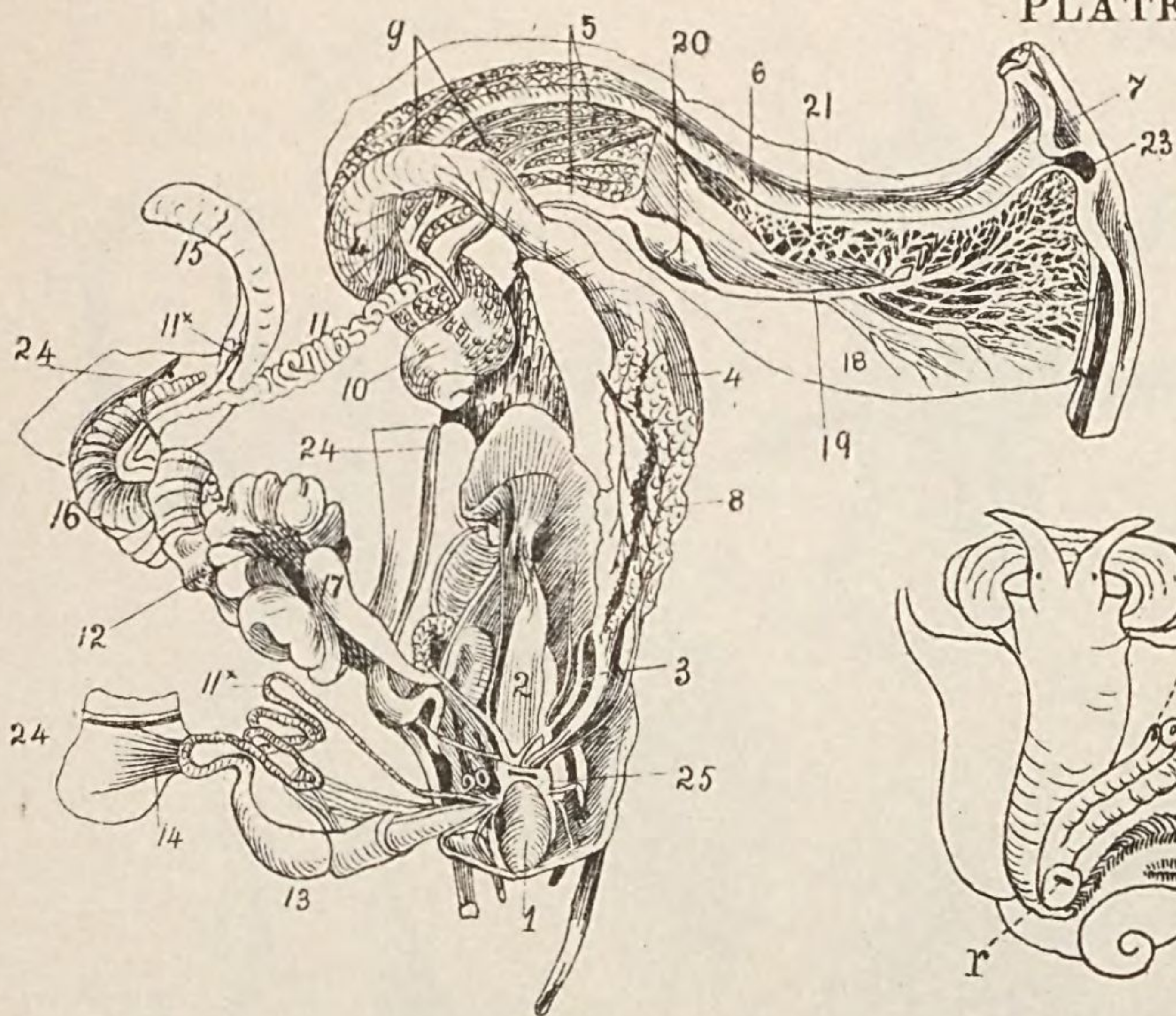
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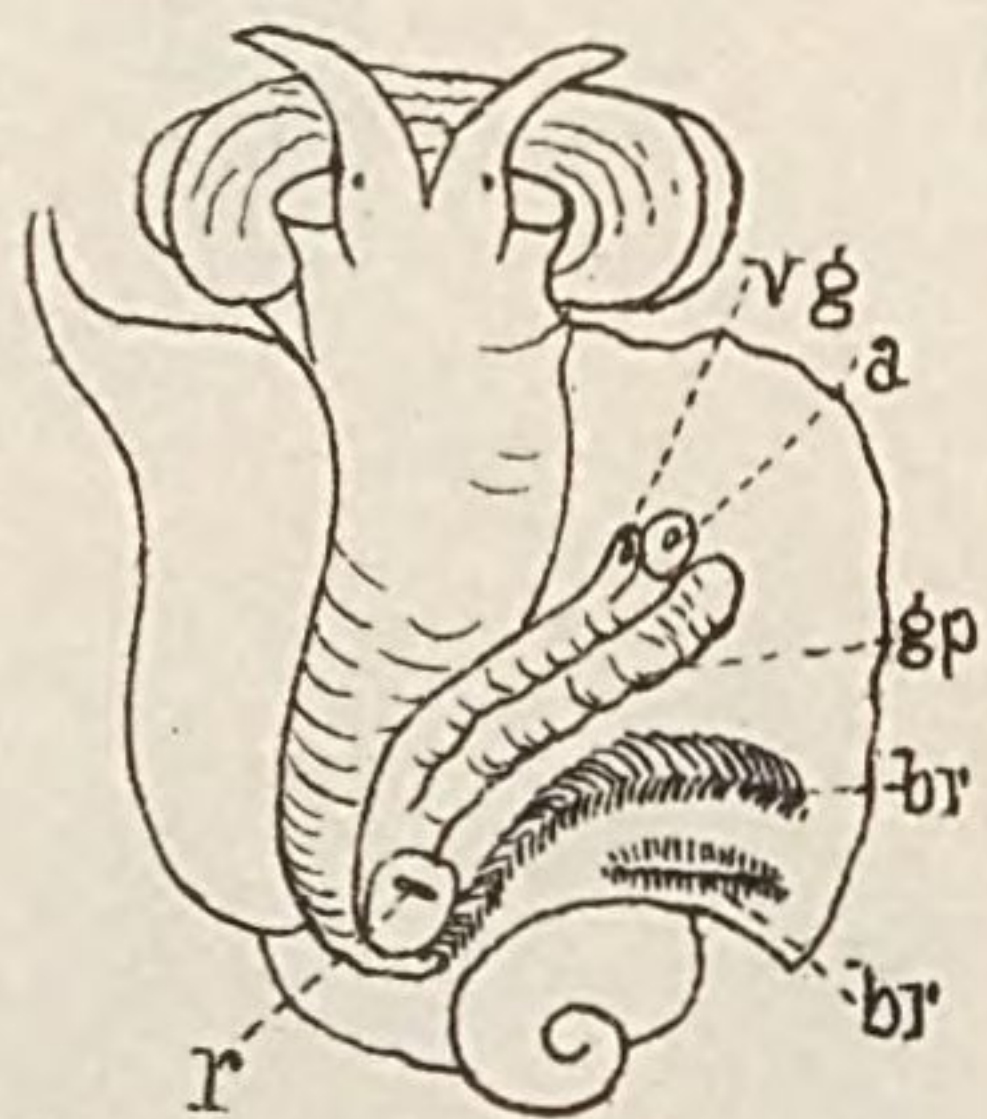
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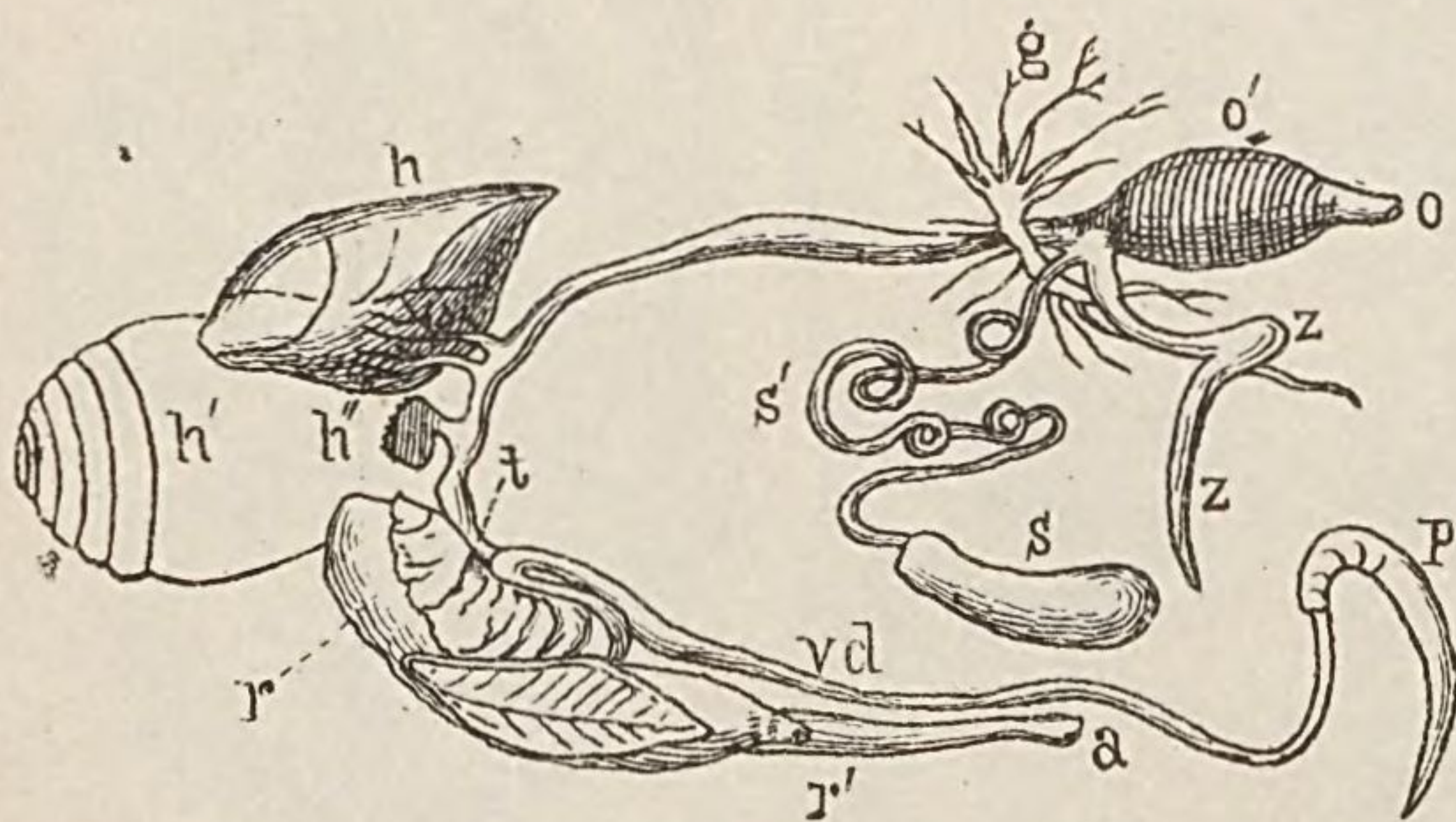
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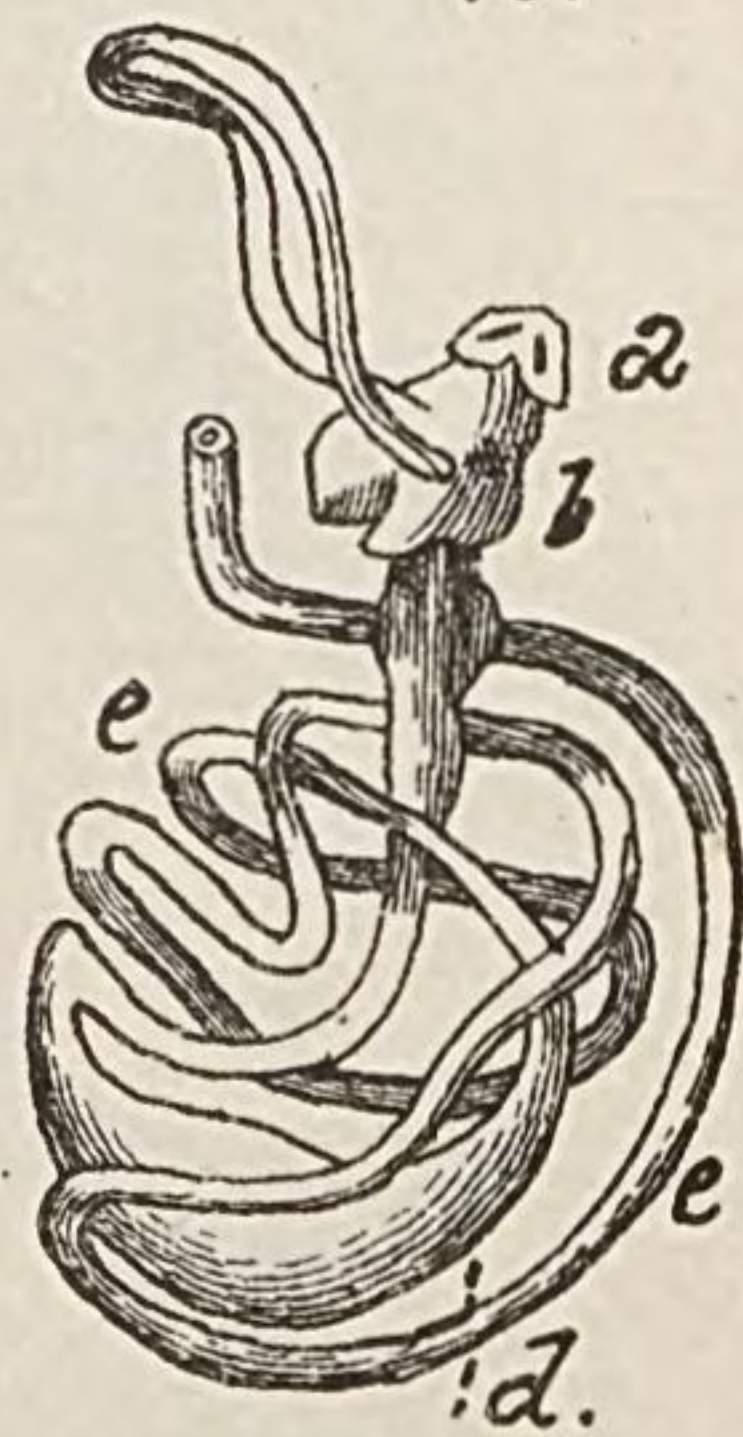
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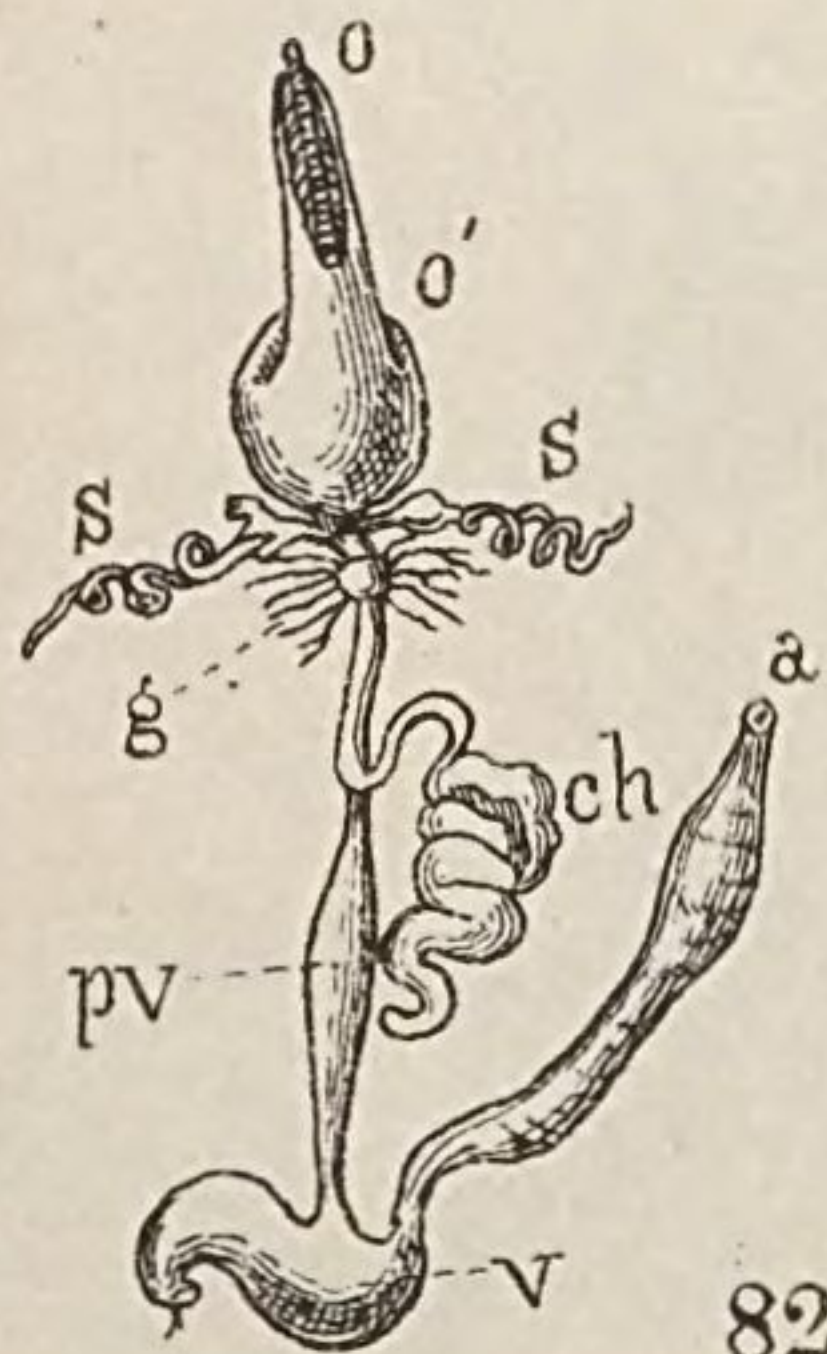
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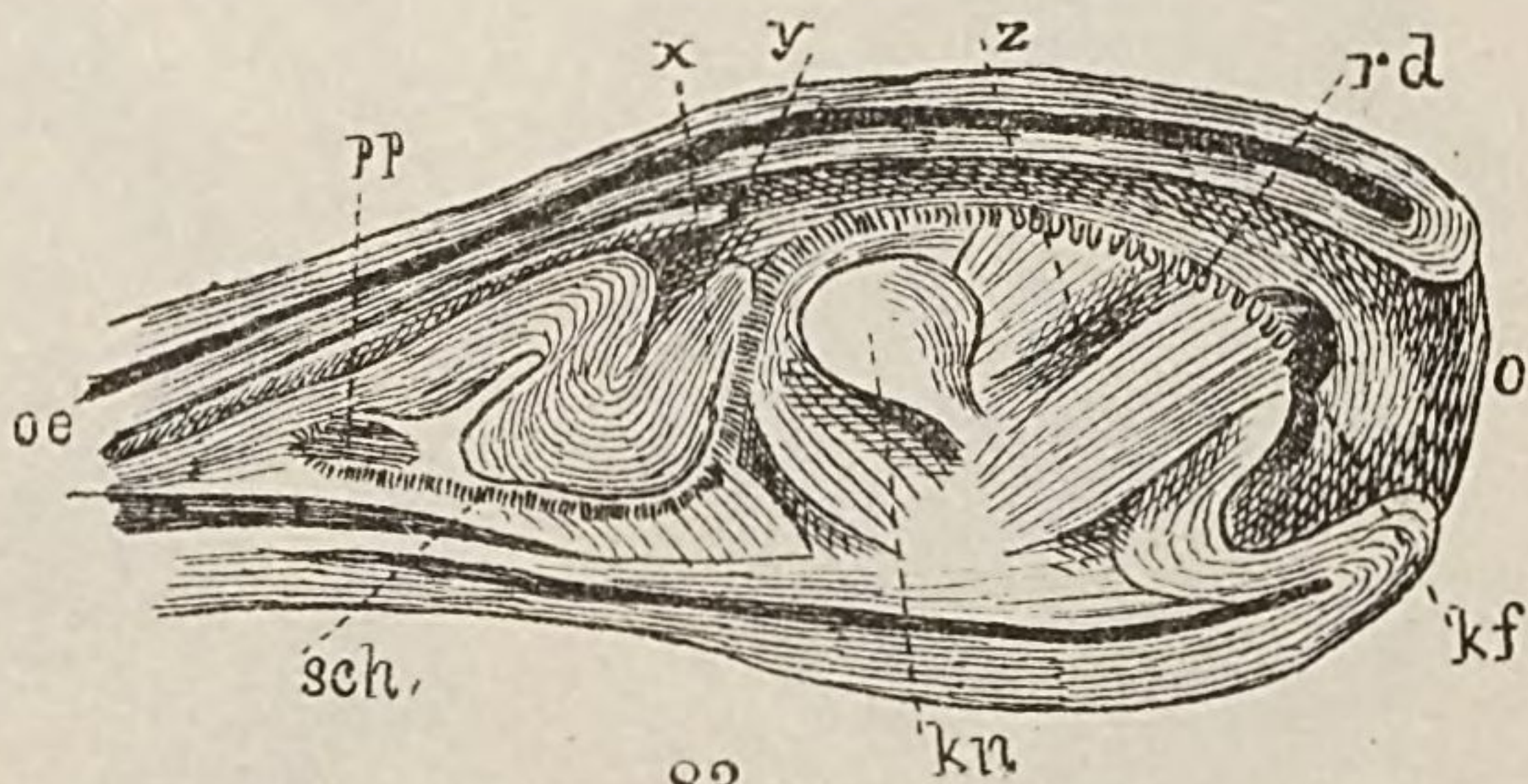
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81.



82.



83.

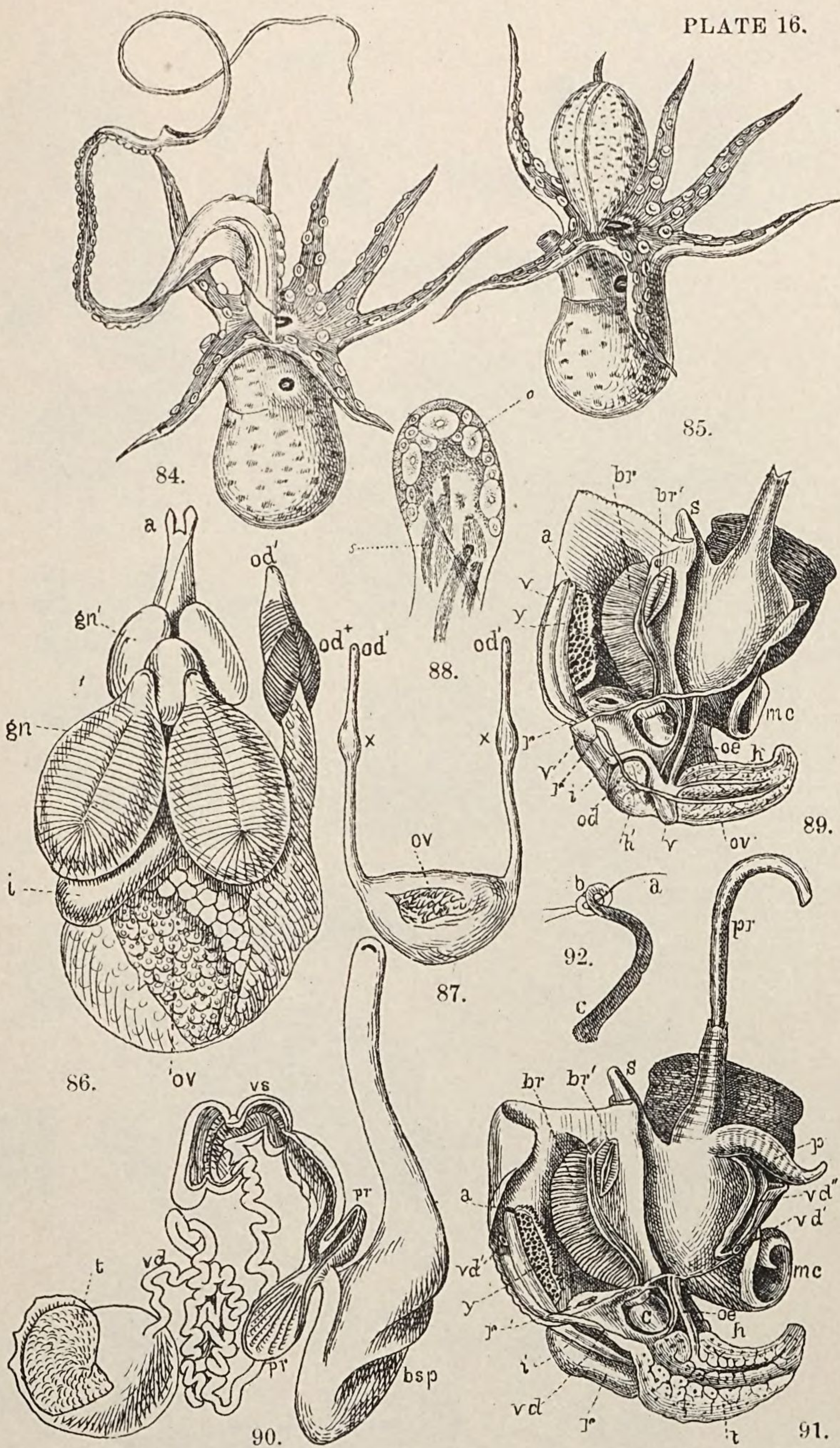
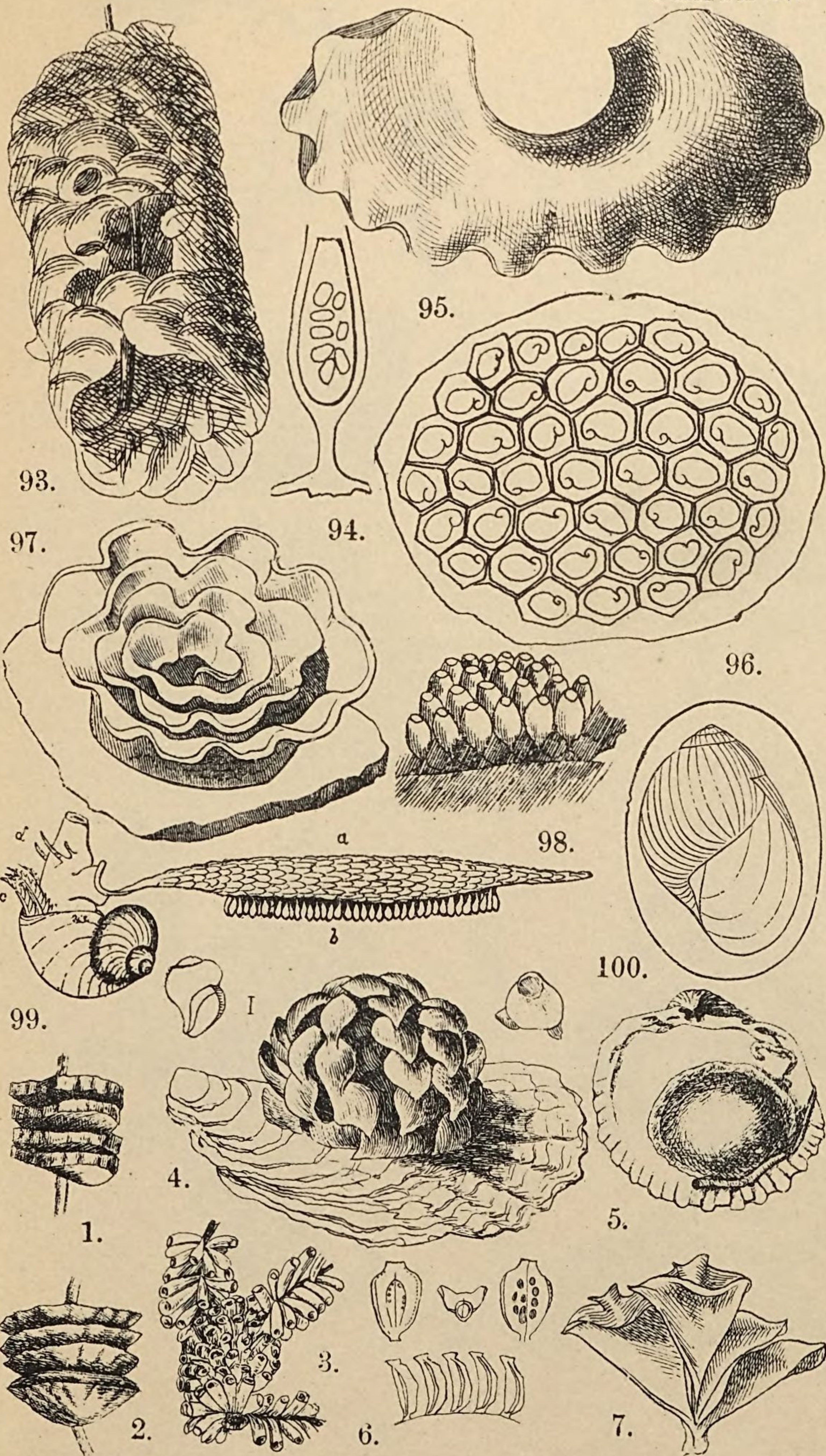


PLATE 17.



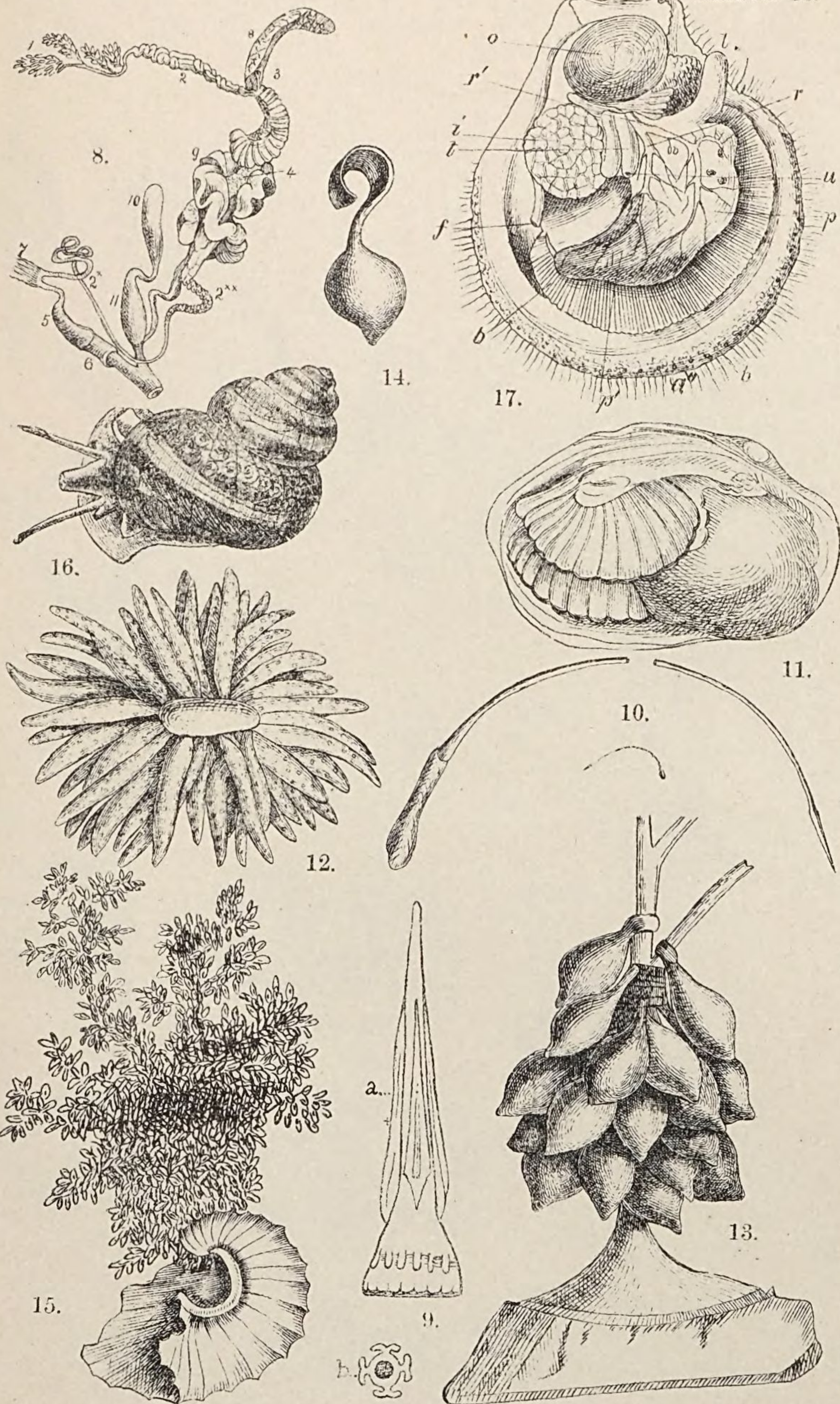


PLATE 19.

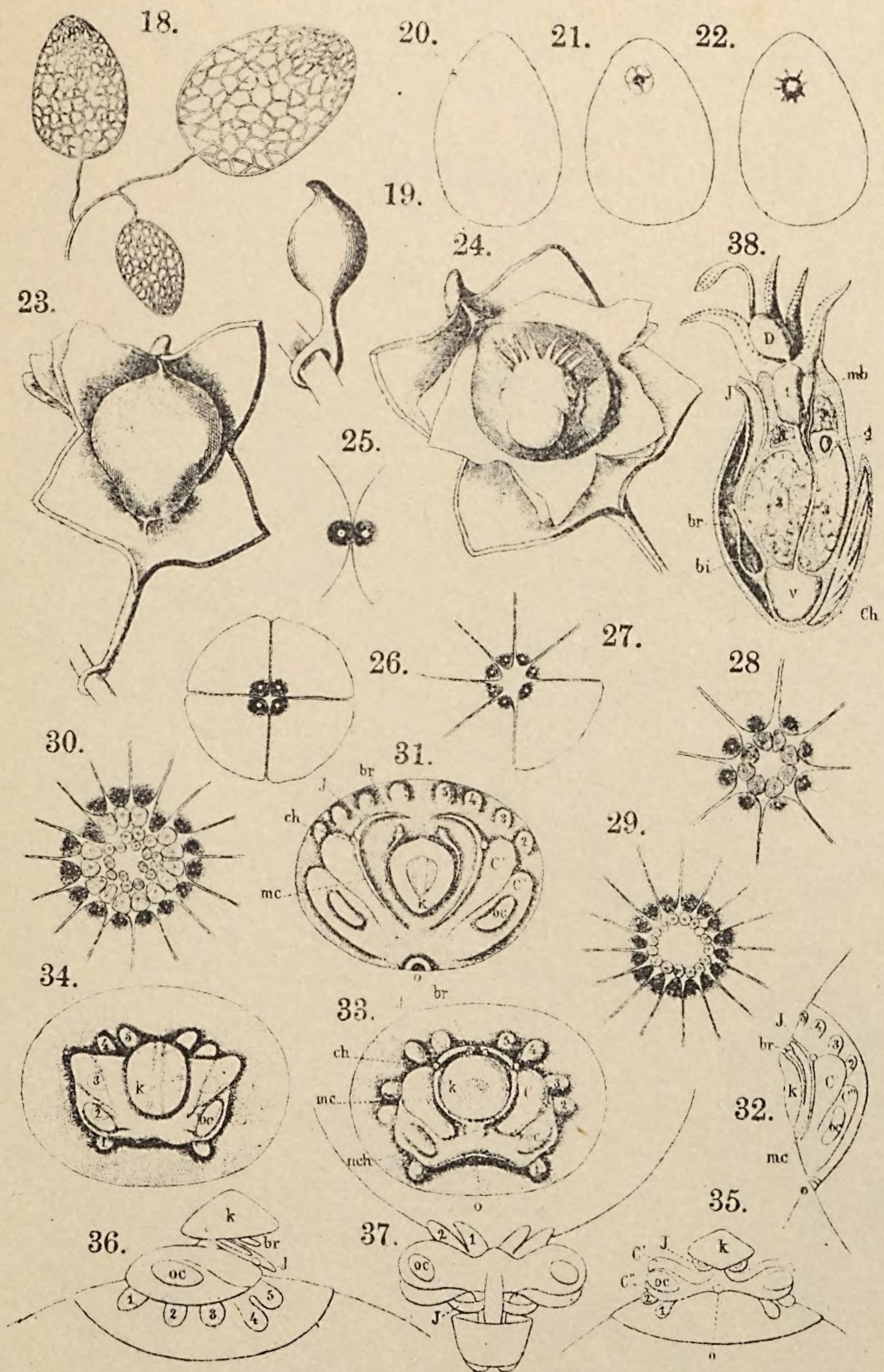


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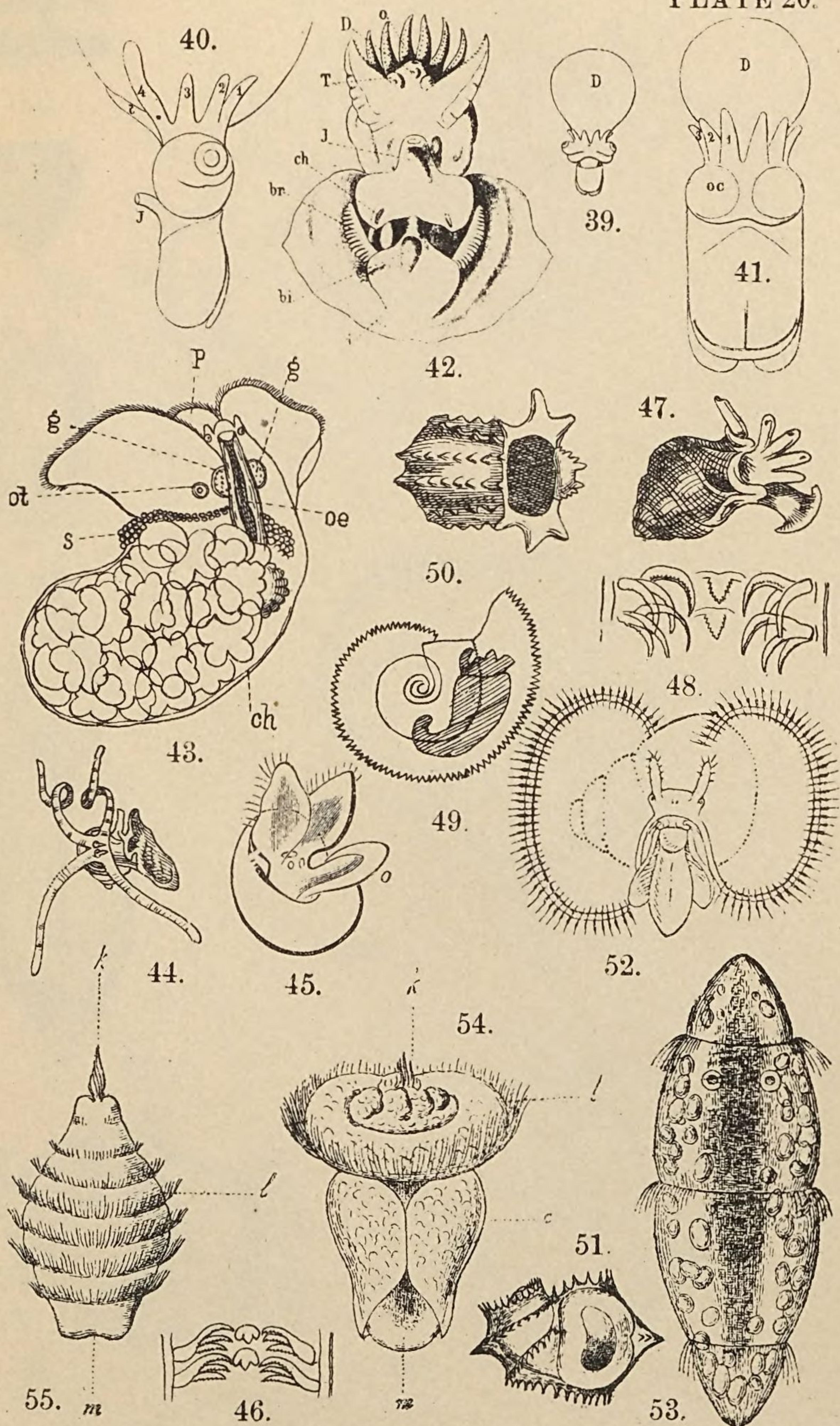
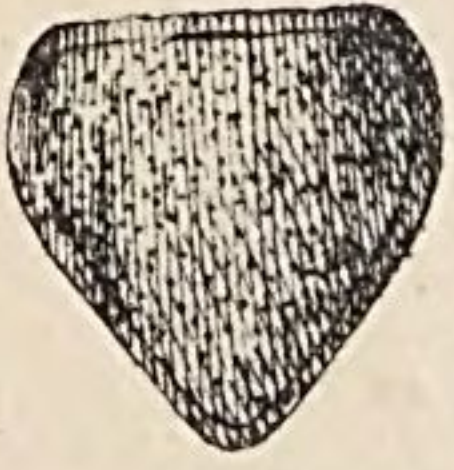


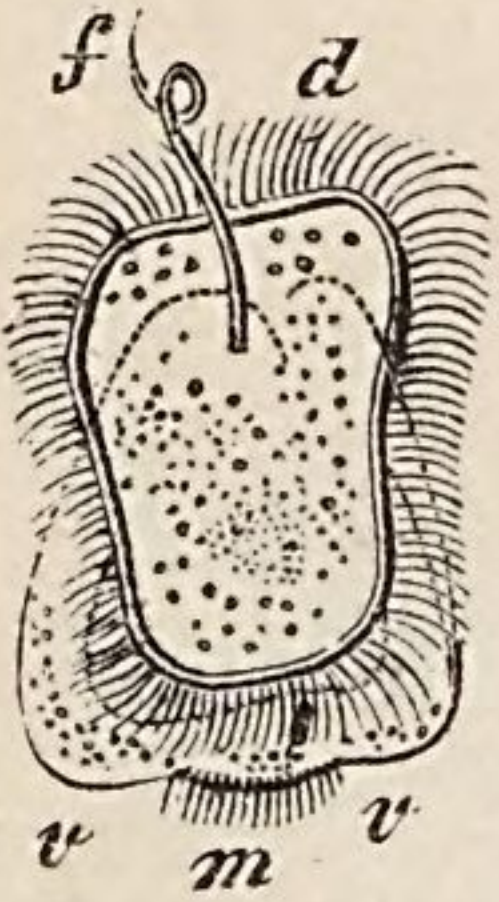
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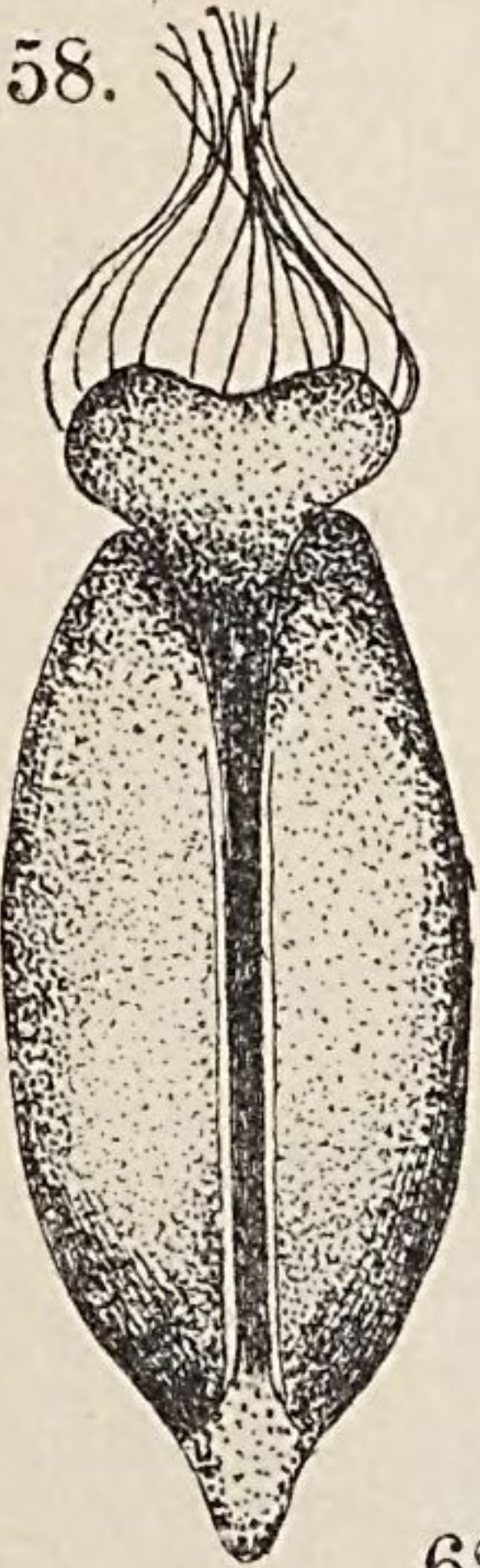
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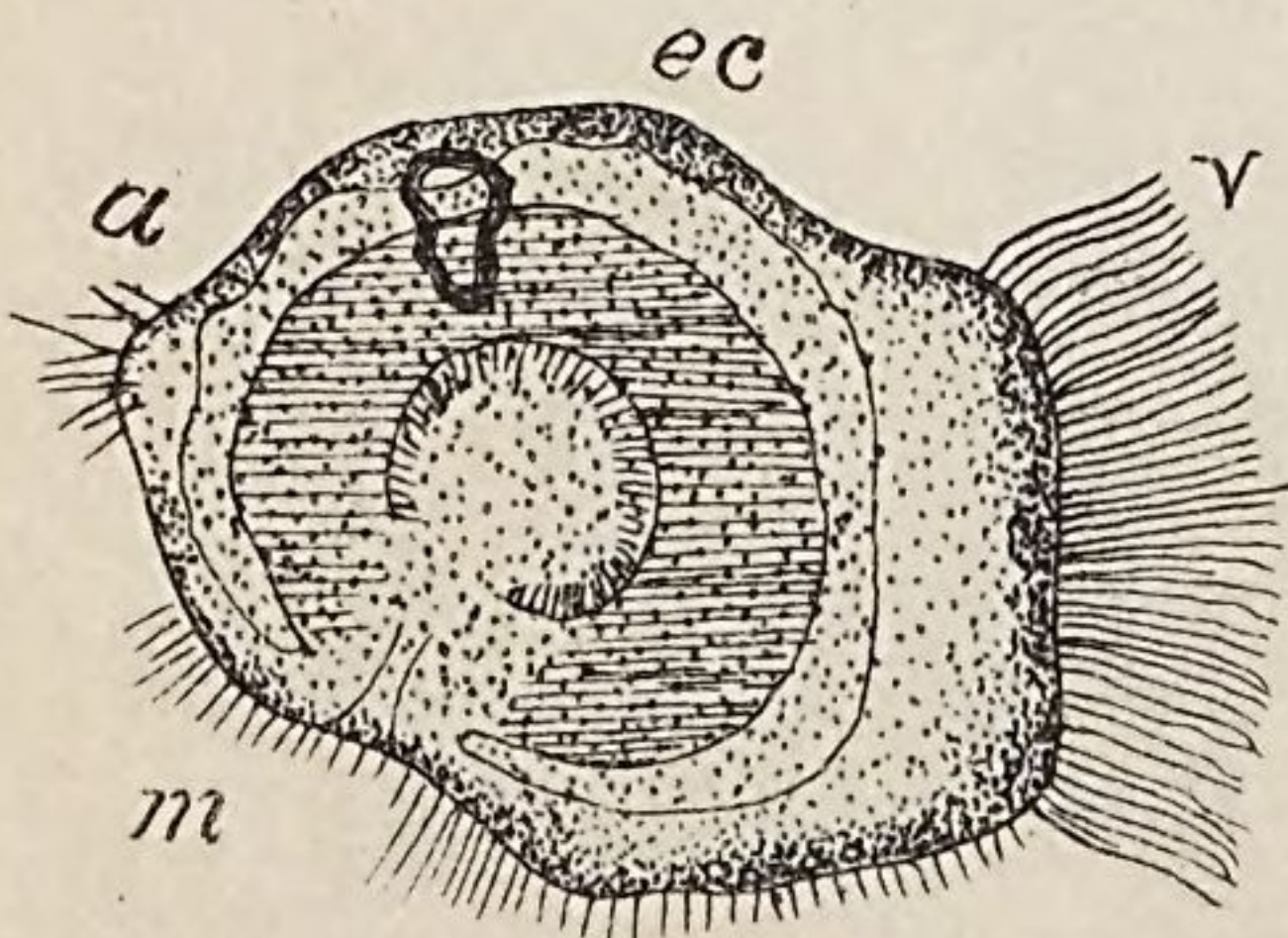
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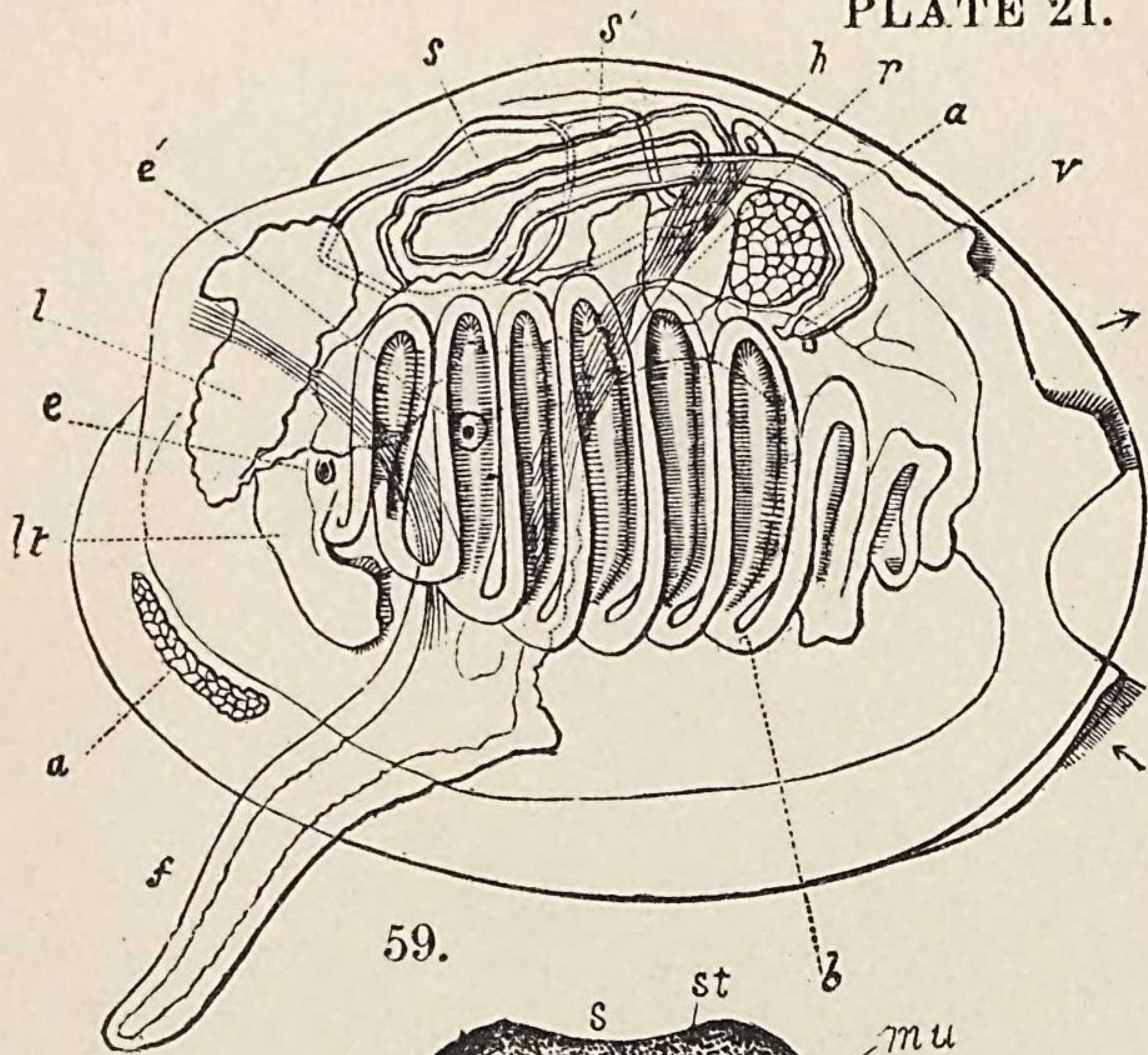
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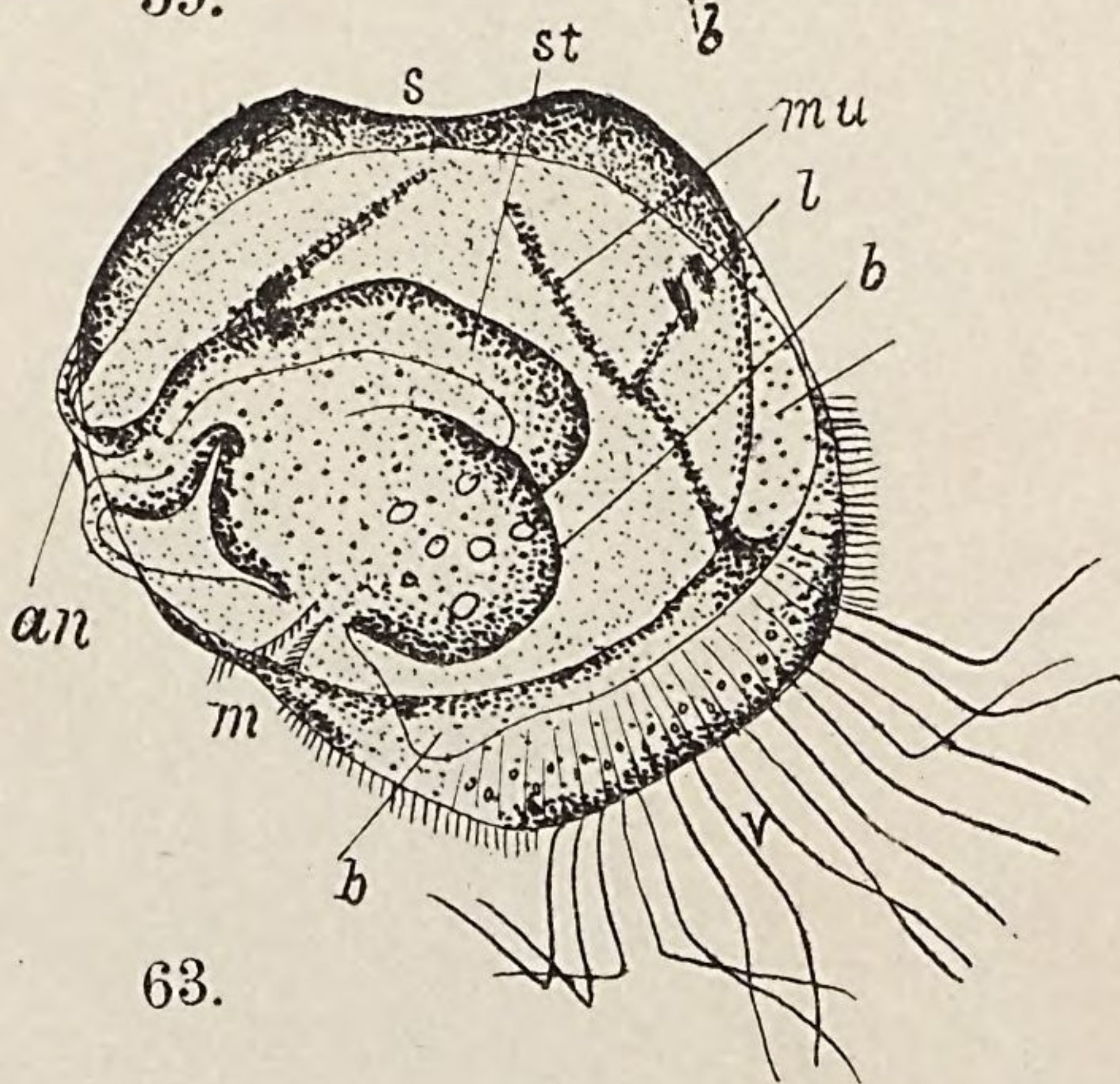
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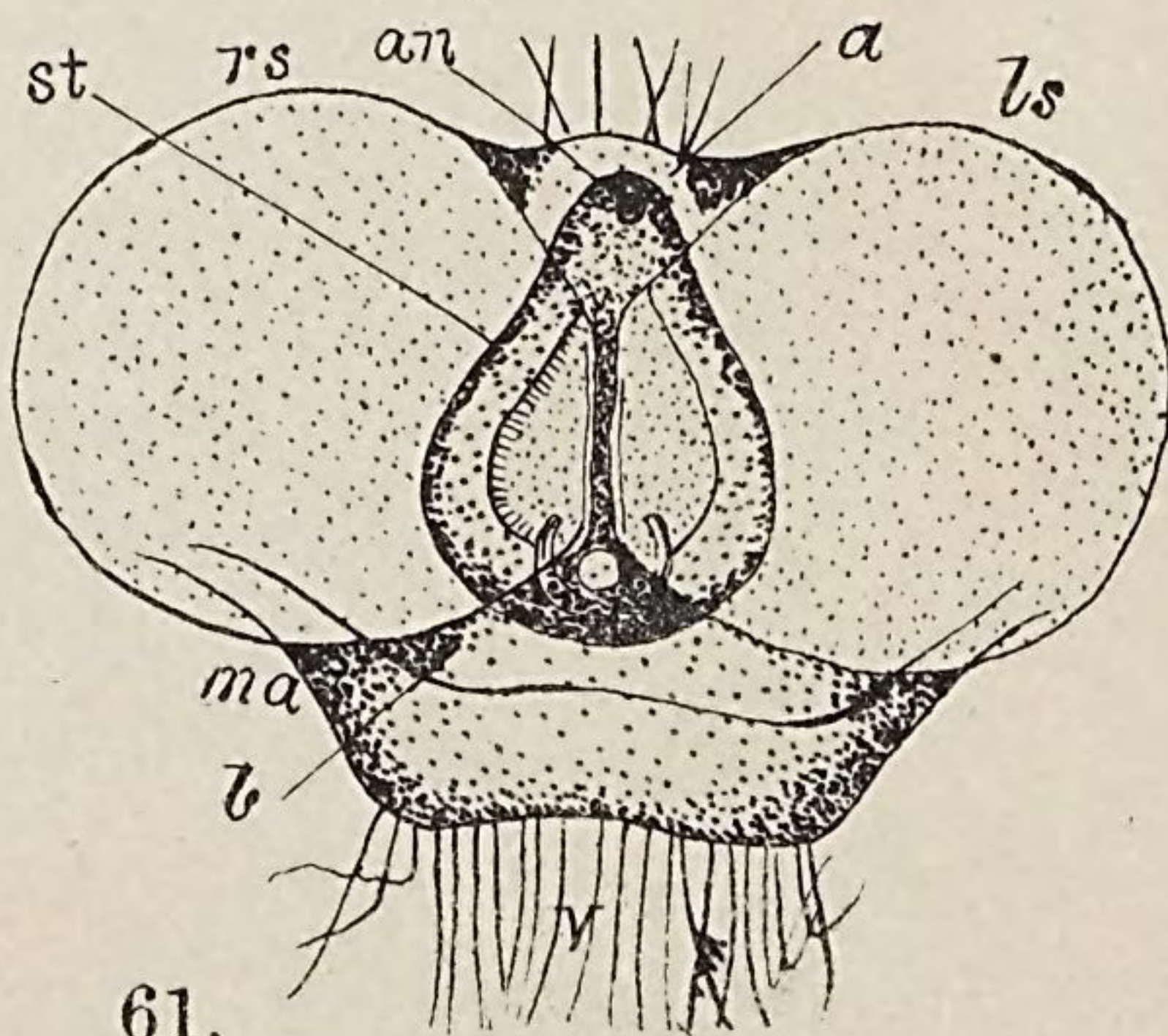
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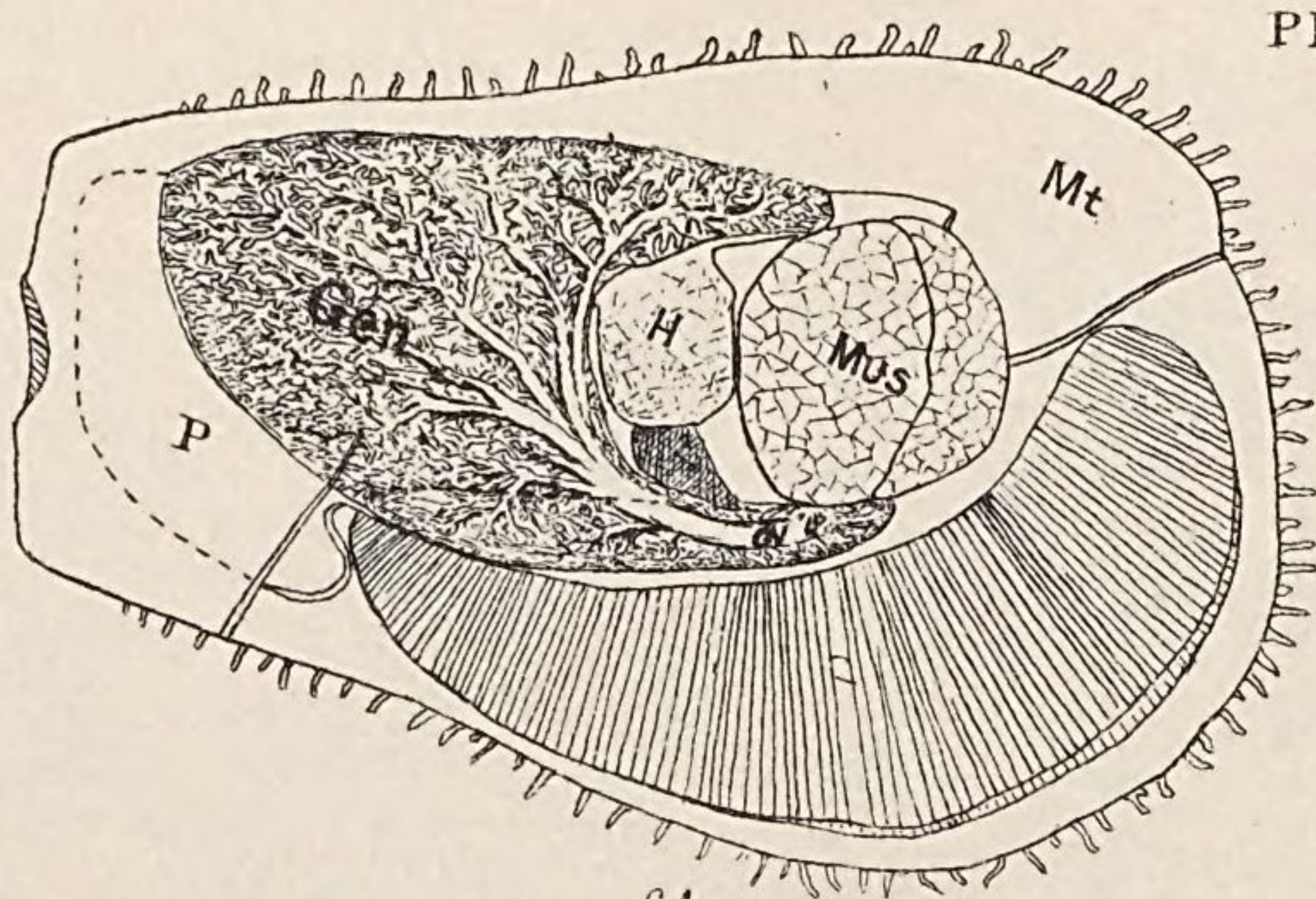
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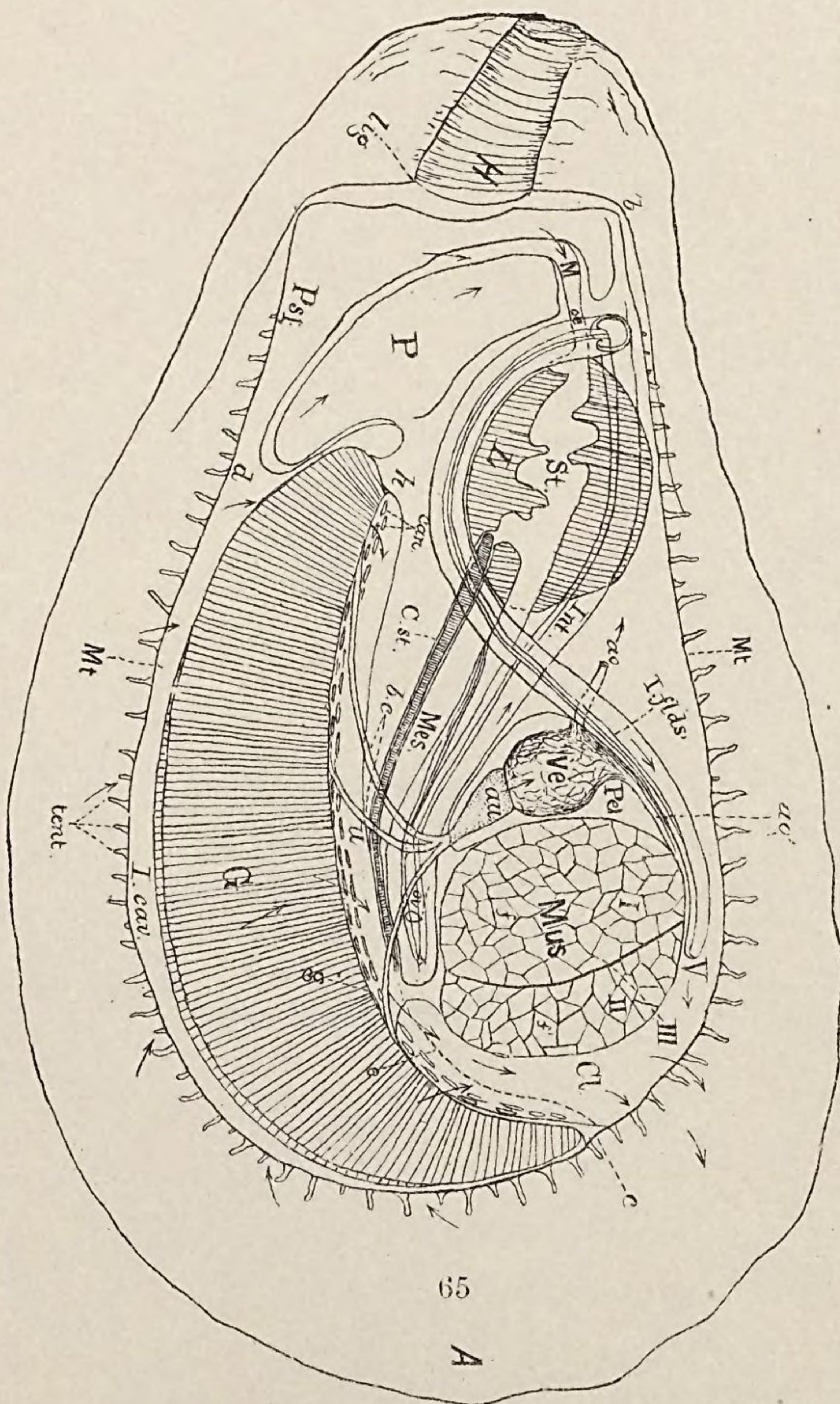
63.



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A



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